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Dear Nuts and Volts:

I had to write and congratulate your writing staff on publishing the perfect electronics magazine. I have found the new format for this magazine to be very interesting. I love the projects you have selected, "Q & A," and the computer projects. I enjoyed the history of the Internet and BBS. I would love to see more of the history of electronics and computers. Future articles could be on the history of some of the first personal computers.

"Just for Starters" is an excellent section, too. Even people who have been in the field of electronics for years need a refresher and a new point of view that this section provides. Keep up the good work!

Steve McCormick
via Internet

Dear Nuts and Volts:

I must strongly disagree with recent articles on where electronics is headed. I do agree, in part, that there are changing directions; however, based on recent applicants where I work, no one is getting a proper technical education.

While I understand that there is (or was) more work with computers, when applicants with fresh tech school degrees are unable to explain series capacitor circuits, *something* is missing. We begin to wonder whether they are getting their money's worth at the schools they attended.

C. Hejkal
via Internet

Dear Nuts and Volts:

I just read, "A Simple One-MHz Frequency Counter," in the March issue of *Nuts & Volts*. I would build this circuit if I didn't already have a good counter; it is well explained and looks like it would work well.

I see only one change I would make in the circuit. C1 is shown as a 1.0 µF, 63V polarized electrolytic. I think this should be non-polarized, in case it is connected to a circuit point which has a negative DC voltage. I would use a 1.0 µF monolithic ceramic cap for lower leakage.

Perhaps, since I do some work in electronic music, where tubes are still found, I might use a 1.0 µF mylar or polyester capacitor — the type made for crossovers — rated at 400 WVDC or higher. Also, since the MPF102 has a high input impedance, I'm not sure if a cap as large as 1.0 µF is needed for C1.

Bill Stiles, CET
Hillsboro, MO

Dear Nuts and Volts:

For several years now, I have been intending to share some of my memories of a half century with electronic magazines.

I first subscribed to *Radio Craft Magazine* in 1946, a year before earning my EE degree. About a year later, I met and chatted at length with Hugo Gernsbach at the annual IRE Convention in NY.

In the years since then, I have continually subscribed to your magazine and always read it cover to cover. It is the first magazine I reach for when the mail arrives.

Robert S. Babin
Rancho Palos Verdes, CA

Dear Nuts and Volts:

Would you please check the article, "Learn About Cyclic Redundancy Checks," in the March 2004 issue of *Nuts & Volts*? I cannot verify Mr. Kornacher's math results.

For one thing, how does he get the same answer whether he adds or subtracts the same two binary numbers? His division example also needs more explanation. The problem does not seem to work out, if you walk it through without a guide. Thanks.

Bob Nelson
Quincy, CA

Response:

Thanks for the opportunity to clear things up. I made a special point in the article under the heading, "Modulo-2 Arithmetic," to describe that it was different than the usual type of binary addition, but I guess it wasn't clear enough. Anyway, here's another explanation.

As I stated in the article, modulo-2 arithmetic is not your standard binary addition and subtraction. In standard binary addition and subtraction, you are always concerned about carries and borrows. This is exemplified by digital full-adder circuits. However, in modulo-2 arithmetic, we are not concerned about carries or borrows. This is exemplified by digital half-adder circuits. A half-adder circuit is simply an exclusive-or gate. Therefore, in my example of 1111 + 0110 = 1001, the sum is derived by performing an exclusive-or operation on each column of bits.

If this still is not clear, I urge you to enter "CRC" into your favorite Internet search engine and you will find a wealth of information about this subject.

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Author

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Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

Take It to the Skies — Hovering Robots

I have been building and designing land-based robots for the better part of two decades now. I have played with wheeled and legged beasts alike, covering two to eight legs and one to 12 wheels. At this point in my life, I really feel that I have to expand my horizons. Since I don't have a pool and there is no swimming in the lake nearby, water is out; not having access to active volcanoes left lava out, as well. It is beginning to look like I have exhausted all of my land-based options, with the possible exception of building a burrowing robot. The only option this left to me is to "take to the skies."

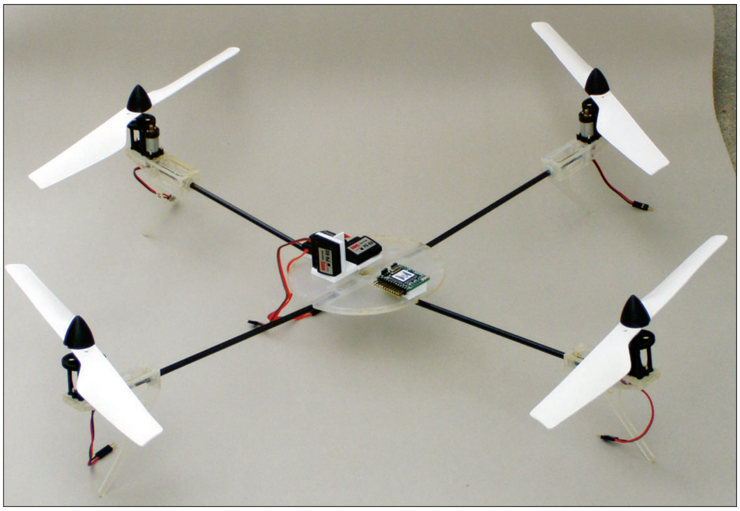
Once I decided to build a hovering robot, my first reaction was to rush out to the hobby store and pick up one of those little electric helicopters that the spammers were pushing this past holiday season. I had looked into these before and there were two names I knew: the GWS Dragonfly and the Century Hummingbird. I decided on the more expensive option — the Hummingbird — which was available locally, but later found that the Dragonfly was 99% identical and a lot cheaper.

Straight out of the box, the Hummingbird's performance was a bit lacking for robotics. Every rotating component was just adequate to fly, but I felt that the control aspects would be too daunting to attempt as is. The problem came down to response time. Every little linkage has a bit of slop and a good number of components bend a little, especially the main blades and rotor head. All this adds up to an over damped system. It is very docile for the human user, but trying to make a damped system perform can be frustrating.

I honestly could write a book on how to set up and modify this little helicopter, but there is a forum that contains all of the information you need: **runryder.com** Really, what it amounts to is replacing a good number of components with aftermarket components — some more expensive, some less, and all better performing. Carbon fiber blades and Lithium Polymer batteries are all very exotic.

After my evaluations, I determined that I could lift my IsoPod, with a little mass to spare, but I would be better off with a brushless motor. The problem was that, after numerous crashes and upgrades, it was getting hard to justify all of the added expense. After all, this is supposed to be an article on autonomous vehicles for robotics, not hobby flying.

The "quadracopter" test rig.



Plan "B"

At work, I am an "off-the-shelf guy," working miracles in record time by taking advantage of someone else's R&D dollars. For some unknown reason, I decided to undertake a complete engineering task as my plan "B." Some mysterious demon — which I have yet to completely exorcise — told me to blatantly copy the Draganfly (not to be confused with the GWS Dragonfly) from **RCToys.com** The Draganfly is a highly engineered piece of equipment that incorporates a few noteworthy key features.

For those of you who haven't seen it — taunting and mocking, flitting through the stratosphere like, well, a dragonfly — the Draganfly is a unique hovering platform that uses two pairs of motors and propellers that rotate in opposite directions. Imagine a "+" sign with propellers at the ends. The top and bottom

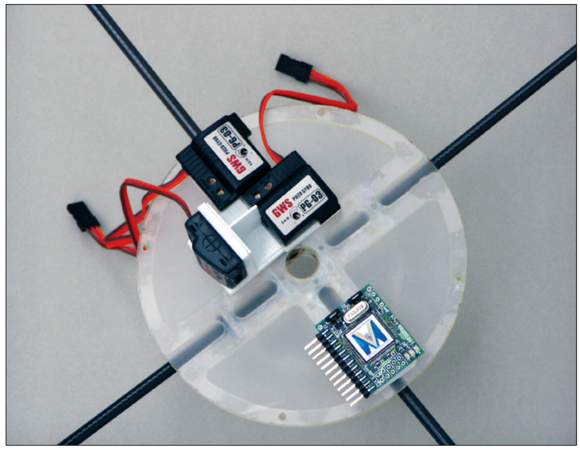
propellers rotate clockwise, while the left and right ones rotate counter-clockwise. The reason for this is that, if all of the motors turned in the same direction, the craft would have a very strong tendency to rotate. By altering the speed of different pairs of motors, you achieve rotation. By altering the speed between opposing motors, tilting occurs, which causes lateral translation.

The one feature of the Draganfly that is difficult to emulate is its propellers. They are shaped more like a scoop than the propellers that we are accustomed to seeing on an airplane. This is because this type of propeller is the best choice for one that needs to generate a lot of thrust, but does not have a high forward speed as it goes through the air. Since we have a lot of batteries, microcontrollers, and sensors to move, the deep scoop shape of the Draganfly's propellers is perfect.

This is also similar to the type of propeller you find on slowflyer aircraft, which generally have a lot of thrust, a large diameter, and a lot of pitch. The propellers, it turns out, were my undoing, but more on that later.

At least it turns out that finding motors to drive these exotic propellers is straightforward. GWS has a multitude of different propellers and motor assemblies, but what they do not have (nor did anyone else I could find, with the exception of **RCToys.com**) was a slowflyer propeller that is meant to turn in the opposite direction (called a pusher or left-hand propeller). Well, I figured that I was going to do a serviceable job of really bugging the folks at RCToys.com just by building a clone of their product, so I wasn't about to add insult to injury by doing the obvious thing and buying their propellers. Besides, where is the fun in just buying a propeller?

I needed to start designing somewhere, so I dove into the engineer's best friend — the spreadsheet. GWS publishes very complete specifications of their motors with different propellers, so I started compiling a mega spreadsheet in Excel. I was looking for net thrust overall, so I built a table that accounted for the mass of the motors, various battery combinations, processors, and sensors. I then looked for a balance of efficiency, overall current draw, and total thrust, in addition to the total number of batteries I would need from my stock of common batteries and motors.



Brainpan of the robot.

I determined that the GWS IPS-DX-CXC motor/8.6:1 gearbox combo with a 12 inch diameter propeller and an 8 inch pitch would be the ideal gear-motor/propeller combo. Add to this an iRate 1300 mAh Lithium Polymer pack from **Lightflightrc.com** and you have a respectable amount of thrust and reasonable runtimes. It was now just a simple matter of making a propeller.

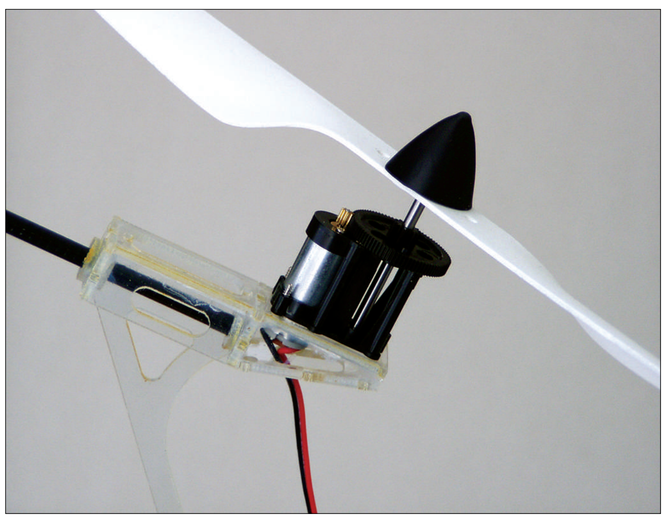
Exactly copying a propeller wasn't a practicality by any stretch of the imagination and mirroring it for left hand rotation was even worse. The one thing I do have at my disposal is laser cutting from my friends at **Filener.com** I decided that I would make a cylindrical fixture that I would curve laser cut plastic around using a heat gun. I designed a separate plastic hub with a hexagonal cutout to match the locking nut on the motor shaft and then I would simply bond the two together. On the computer screen, it was brilliant.

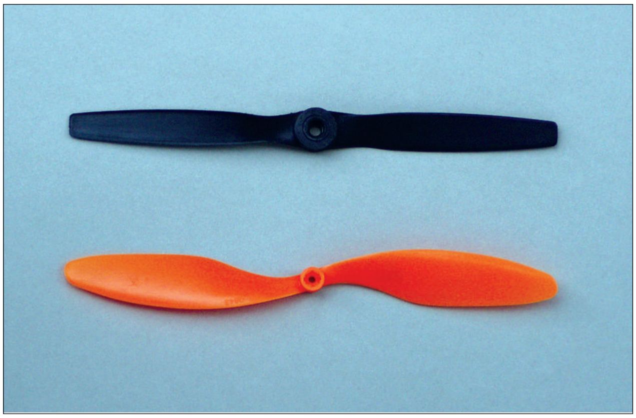
Now, what shape to cut the plastic into and what shape to make the bending fixture ...

I looked up propeller design on the Internet and I found so much information that it was amazing. All I wanted to do was bend a little plastic. I determined that all I could really do for a fixture was make a cylinder and I couldn't find anything that covered propeller designs that looked remotely like what I was capable of producing.

In my search for different propellers, I looked at my helicopter's main and tail blades and the stock GWS propeller — and guess what? They all looked like they could be wrapped around a cylinder. That made me feel better. The next feature that I knew about was having more lift at the hub than at the tips. To do this, I would have to generate a special shape of blade to get the gradient in lift.

Close-up of the GWS motor, 8.6:1 reduction and prop.





Fast prop vs. the slowflyer prop.

Imagine taking an airplane wing and making the air moving past its tip move at a higher speed than at its base. This gradient in lift could actually cause it to bend and break. A propeller with a high tip speed needs a greatly different, flatter shape than its inner diameter. The key is to design a shape that produces uniform lift, regardless of its surface speed.

It all sounds so very simple, but would you believe that your faithful friend and long-suffering narrator has spent yet another small fortune on laser cut blanks that were too thin and a fixture that sucks the heat away from my blades? I really do not know what possessed me to ask for 1 mm thick material, but I did.

Somehow, I knew they would be floppy, but deluded myself. To date, I have gone through almost two dozen blades and, as I write this — still coming down from a molten nylon fume induced “bad trip” — I have nothing to show for my efforts except for a heap of molten blade slag.

Well, my saving grace came from the site where I had purchased the carbon fiber tubing that I intended to use for the structural elements. You can actually buy propellers to build something called a "Roswell flyer," which turns out to be exactly what I set out to do on my own.

Airdyn.com sells a complete set for $19.00. I tested them and found that, with a slightly different gear ratio than the one I had intended, you can get 4.5 oz of thrust at less than 2 amps of current.

I had planned on continuing my "propeller quest." My next attempt was going to use a thicker material, "cooked" in an oven over my form and fixed to a machined hub. I was also looking at thin, wood laminate, which I would have laser cut with different grain orientations. These would be curved over my form with moisture and heat (if my wife would trust me with her Oreck Steam Cleaner), then sanded, balanced, and lacquered — like a real airplane propeller — but this off-the-shelf solution was just too easy. I may also make a blade out of carbon fiber using my existing form and vacuum bagging techniques.

Here is a rundown of my design so far:

I have four GWS IPS-DX-CXC motors, which — when combined with my propellers — give me about 18 total ounces of net thrust. Take this and subtract the following:

(1) iRate battery from **LightFlight**	2.3oz
(1) IsoPod from New Micros, Inc.	0.9oz
(4) GWS ICS-100H Speed Control	0.7oz
(3) GWS PG-03 Gyros	0.3oz
(1) Hitec receiver from ServoCity	0.3oz
Motors and propellers	7.5oz
Polycarbonate chassis components	1.2oz

That gives me approximately six ounces of surplus thrust, which is plenty for hovering around.

Once I get the technical snags of the build worked out, I can get on to testing my battle plan.

Stage 1: Testing

The center core of the airframe is hollow. This will allow me to build it onto a 3' long dowel and see if it will just lift its own mass. An undersized dowel will allow it to rise and fall, while still keeping it relatively safe. Here, I will re-evaluate the strength versus the mass and redesign any of the mechanics that need attention. I will also be able to fit my batteries and speed controls in, as well as my IsoPod, once all the mechanical issues are squared away. In addition, I can also refine my propeller design as necessary

Stage 2: Flight

I hope to put my nearly 20 years of R/C chopper experience to good use. With a simple mixing algorithm — which takes control inputs in and sends out commands to the motor drivers — I should be able to achieve level flight. In order to command rotation to the right and left, I will simply increase the speed of one pair of motors and reduce the speed of the opposing pair. This will result in the same amount of overall thrust, but a change in rotational speed of the whole airframe.

The goal here is to simply go up, down, and rotate. This will be done in short, safe hops.

Stage 3: Evaluation

At this point, I will know whether I have an inherently stable platform or not. If it is not stable, it's back to square one. If it is stable, then the next control inputs will be added. In order to move around, we need to produce some lateral thrust.

By causing a difference in the speed of a pair of propellers, the craft will tilt, causing a couple of things.

First, the craft will translate sideways and, second, it will most likely lose a bit of altitude. Sensors that are sensitive enough can correct for the loss of altitude by increasing thrust, for instance. If I can achieve these things, I am set.

Stage 4: Everything Else

If all has gone well, I will have a platform that is stable enough to carry a sensor package. I have been looking at the boards from **rotomotion.com** and may go for a six degrees of freedom sensor package. My real goal here is to build a small, intelligent vision system and do aerial line following.

Please look to the skies for hovering attack robots. If you see them, you will know that I have succeeded and, if you have ever built your own miniature aircraft propellers, please feel free to contact this humble author at author@bio-bot.com **NV**

Most people settle for just *one* propeller on their heads ...

Electro-Net Go to www.nutsvolts.com — click Electro-Net

Basics For Beginners

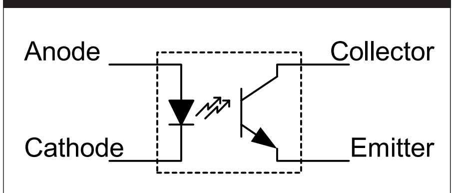
Just For Starters

Interface Choices — Part 2: Optoisolators and Relays

Last month's column began a discussion of interfacing solutions where a digital control circuit drives or senses external or high-current signals. A couple of transistor-based circuits that share a common ground with the control circuit were presented for DC signals. There are circumstances where external signals must be fully isolated from the control circuit. Some equipment must have isolated circuitry to prevent electric shock hazards.

How do you sense a signal that has a separate ground return? How can a microcontroller turn on an AC light bulb? The basic problem in both cases is how to transfer a binary on/off state from one circuit to another.

Figure 1. Integrated optoisolator schematic symbol.

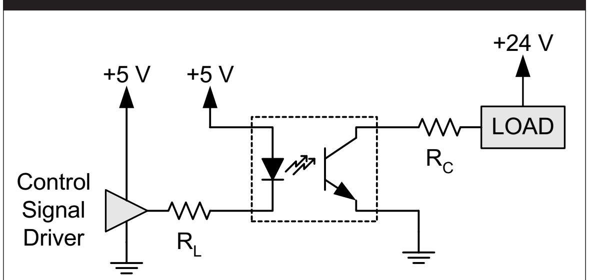


Optoisolators

Optoisolators, or optocouplers, are easy-to-use isolation mechanisms when a common ground is unavailable or undesirable. As their name implies, optoisolators use light to transmit a binary state between circuits. The idea is to drive a light source at one end and sense the light at the other end with a photo-transistor. There is no electrical connection or current-flow between the circuits.

Optoisolators may be constructed using discrete components for special applications; however, a popular form is a molded, opaque component with four leads. Figure 1 shows the basic schematic symbol for an integrated optoisolator. The two leads are the anode and cathode for the driving LED. The other two leads are the collector and emitter for the sensing bipolar junction transistor. Integrated optoisolators are easy-to-use because you don't have to worry about stray light activating the transistor. The LED and photo-transistor are matched for proper responsiveness.

Figure 2. Isolated output with optoisolator.



Optically Isolated Outputs

Figure 2 provides an example of isolating an output with an optoisolator. The control circuit drives the LED through a current limiting resistor, R_L. R_L is sized to provide enough current to activate the LED at the LED's forward voltage, V_F. Assume that V_F = 1.5 V at 5 mA. Also assume that we have a 5 V logic supply and a 74LS-family bipolar logic output. We choose to drive the LED when the logic output is low because bipolar logic can sink (logic-0) more current than it sources (logic-1). Therefore, the LED's anode is connected to the supply rail via R_L and the cathode is connected to the logic gate.

We pick R_L by calculating the necessary voltage drop across it. If we estimate 74LS logic-0 output voltage at 0 V, a total of 5 V must be dropped by the LED and R_L. Since V_F = 1.5 V, R_L drops 3.5 V. Since the LED's specified current is 5 mA, Ohm's Law gives the nominal resistance: R_L = 3.5 V / 5 mA = 700 Ω. 680 W is a standard value close to our calculations that errs on the side of a little more current through the LED.

Treatment of the isolated transistor side depends on what is being driven. Figure 2 shows a generic load connected from the isolated supply voltage to the transistor's collector through a current limiting resistor, R_C. The isolated load can operate on completely different supply voltage rails.

This example utilizes a separate +24 V isolated supply. There are a couple of issues to pay attention to when directly connecting a load and optoisolator. First, the output transistor has a rated collector current that

should not be exceeded. High-current optoisolators are available if your application demands it. Second, the transistor has a maximum rated collector-emitter voltage, V_{CEO}. Typical values for V_{CEO} are tens of volts. V_{CEO} is highest in this circuit when the transistor is turned off. When the transistor is on, its behavior approaches that of a short circuit and exhibits a saturated V_{CE} of approximately 0.3 V. V_{CE} climbs as high as 24 V in this circuit when the transistor is off and no current is flowing through R_C and the load.

Optically Isolated Inputs

Optically isolating an input uses the same basic circuit in reverse. The circuit in Figure 3 drives the LED with an output that swings from 0 to 24 V. R_L is chosen as before, with the continued assumption of V_F = 1.5 V at 5 mA: R_L = 22.5 V / 5 mA ~ 4.3 KΩ. On the control circuit side, a pull-up resistor (perhaps 4.7 to 10 KΩ) keeps the input at logic-1 until the transistor turns on and pulls the input to ground. This circuit topology inverts the control signal because the isolated signal drives the LED when it transitions from 0 to 24 V.

Relays

Optoisolators are limited in their power applications because they are semiconductors. Very high voltages and currents are difficult to deal with in semiconductors. A basic transistor circuit is also not suited to AC-powered loads. Relays, however, can handle AC power and a wide range of voltages and currents.

On one side of the relay is an electromagnet; its coils are energized by the driver.

At the other end is a magnetically actuated switch. The basic schematic symbol for a relay, shown in Figure 4, reflects this structure. Relays are made in many switch configurations, ranging from single-pole-single-throw (SPST) to double-pole-double-throw (DPDT) to many-pole-double-throw. They are simple devices whose strengths are electrical isolation from driver to switch and a passive metal switch element.

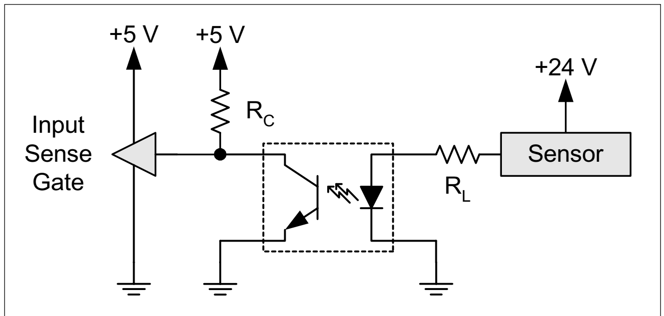


Figure 3. Isolated input with optoisolator.

The magnetically actuated switch is comparable to a mechanical light switch. You can connect the switch to any AC or DC load, subject to the switch element's maximum current rating. Relay manufacturers specify how much current the switch can handle at certain voltages. Current ratings are often in two categories: current at a mid-range DC level (e.g., 24 VDC) and at an AC-power level (e.g., 125 VAC).

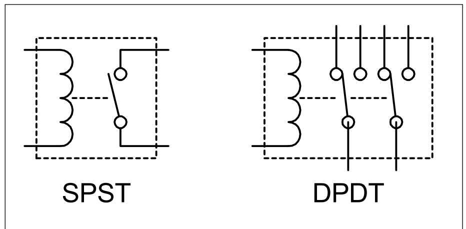


Figure 4. SPST and DPDT relay schematic symbols.

Relay coils are rated with a voltage and current or a voltage and resistance. The driving circuit must steadily apply power to maintain the relay in a switched state; however, there are latching relays where this is not the case. Relay coils are made with different power levels, which are related to the size of the switch element being actuated. A relay coil may require 100 mW — or much more.

Driving a Relay Coil

Relay coils often require more current than a digital IC output can provide. A transistor circuit can be used to amplify the relay control output. Figure 5 shows a coil driver

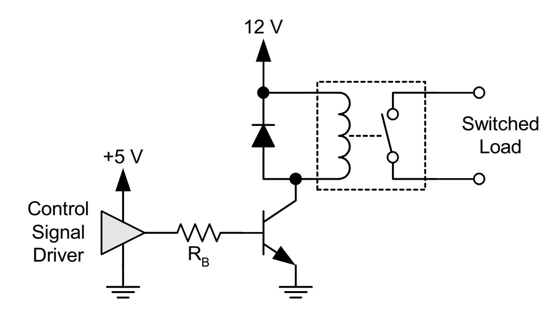


Figure 5. Transistor-based relay coil driver with protection diode.

circuit with a protection diode. While the IC output may be limited to a few milliamps, the transistor can be selected for higher currents.

Still, very high current requirements are rare. A 10-amp relay's coil may require 20 mA at 12 V, which is well within the range of small signal transistors.

A protection diode dissipates the coil's energy when the transistor turns off. Coils, or inductors, resist changes in current flow. The coil voltage reverses in an attempt to maintain current flow when the transistor turns off. The diode is placed so that it is reverse-biased under steady-state conditions: the anode is at a lower voltage than the cathode. However, when the coil voltage abruptly changes, the diode becomes forward-biased and allows the coil's stored energy to dissipate safely.

Sensing an AC Signal

The relay can be turned around so the control circuit can sense the presence of AC voltage.

However, provisions must be made for driving the coil with an AC signal. One solution is using an AC relay. Another solution is rectifying and filtering the AC signal so that it can drive the DC coil. The most practical solution for many situations is replacing the relay with an optoisolator and a rectifier. The optoisolator provides electrical isolation and can certainly handle the small currents involved in logic sensing.

Safety Above All Else

It should go without saying that safety is the primary design issue, especially when interfacing requirements lead to manipulating potentially dangerous currents and voltages. Isolation alone does not guarantee a safe product, regardless of the interfacing scheme in use. All components and wires should be conservatively rated for power, current, and voltage.

Don't be shy about seeking advice from others who have experience solving these types of problems. You can feel confident in the result when you take the time to build safely. **NV**

About the Author

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high-tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design, Mark has actively participated in industry standards committees and has presented work at technical conferences. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at mark@completedigitaldesign.com

The Latest in Networking and Wireless Technologies

Open Communication

Digital Broadcast Radio, Hear Now

AM/FM broadcast radio is about to go digital. It's about time — almost everything else is digital. Digital radio offers some amazing benefits for radio listeners. This year, you can begin to take advantage of them.

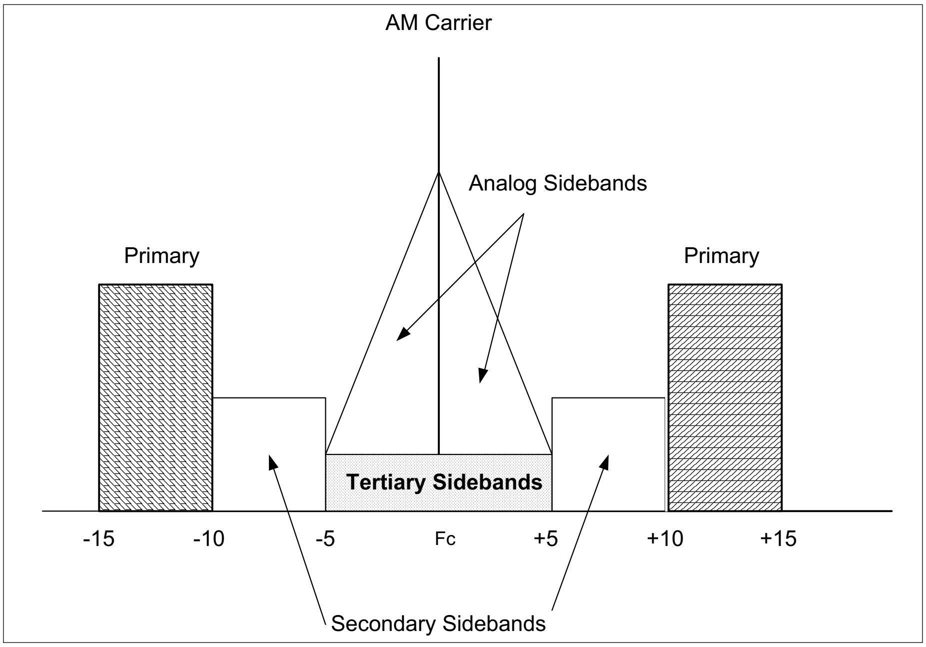
Just about all radio communications today have gone digital. The biggest sector is cell phones; in the past decade, they have transitioned from their FM analog roots to become fully digital. Most military radios are now digital. Even television — while still largely analog — is now available in digital form: high definition TV (HDTV). Of course, satellite TV has always been digital. Even amateur radio is using more digital methods.

Yet, there are still some hold outs, such as CB radio, the Family Radio Service (FRS), two-way commercial radio, as well as marine and aircraft radio. No doubt, they will eventually succumb to the digital fever.

Broadcast radio actually went digital when the new satellite radio services offered by Sirius and XM Radio came online in 2002. (See my column on Sirius Satellite Radio in the October 2003 issue of *Nuts & Volts*). This year, however, many long-time analog AM and FM radio stations will add a digital mode to their broadcasts.

The following outline shows all of the various radio broadcast types currently available. Digital broadcast radio is already well entrenched — mainly in Europe and some areas of Asia. Digital short wave radio may not be far behind.

Figure 1. HD Radio AM hybrid spectrum.



Types of Broadcast Radio

A. Analog
- **1.** AM/FM — US and Worldwide
- **2.** Shortwave — Worldwide (3 to 30 MHz)

B. Digital
- **1.** Satellite Radio
  - **a.** Sirius and XM Radio — US
  - **b.** World Space — Africa and Asia
  - **c.** Digital Multimedia Broadcast — Japan, Korea
- **2.** Terrestrial Radio
  - **a.** Eureka DAB — Europe, Canada, and Asia
  - **b.** HD Radio — US
  - **c.** Digital Multimedia Broadcast — Shortwave (3 to 30 MHz)
- **3.** Internet Radio — Voice and music via a streaming broadband connection.

This article is an introduction to the new digital HD Radio system for the US.

Why Digital?

There are about 13,000 AM and FM radio stations in the US — over half of the world's radio broadcast stations. We listen to the radio a great deal — FM for music and AM primarily for news, weather, sports, and talk. AM radio may be one of the oldest forms of electronics, but it is

still ticking, although it suffers from some limitations. These are, for the most part, about to be eliminated by the digital versions of radio. The question is why go digital when AM/FM analog radio is still so popular? There are several good reasons.

First, broadcast radio is very competitive. Stations need to do something exceptional to retain their listeners and advertisers. Improving sound quality digitally is one good way. The success of the digital satellite radio services that have already been offered has, no doubt, also spurred the industry into action.

Second, the technology is now available to do it. Yes, I know — just because we can do something with technology doesn't necessarily mean that we should. Yet, that happens all the time in electronics. PC technology is a good example. Who actually needs a 3 GHz, Pentium-based PC? Few do, but we get them anyway. Digital radio is now at that stage.

Finally — and this is the good part — digital radio offers some real, positive benefits. For example, both AM and FM will have greatly improved sound quality. AM will sound more like the higher fidelity FM, while FM will sound more like CD quality audio. Music lovers will appreciate this, as we have certainly become accustomed to the superior quality music and sound of CD, DVD, and MP3 players; it is about time radio catches up.

A key benefit — especially for FM listeners — is the greatly minimized degradation of the signal due to multipath effects, which are caused by signal reflections. There will be less fading and drop out as you are driving. This is not such a problem with FM, but AM is affected by atmospheric effects, like lightning. Digital transmission virtually eliminates all of the pops, clicks, static, and other noise associated with AM and FM reception as we know it today.

Other benefits are new features and data services. With digital transmission capability, the radio stations can now transmit station ID information — such as call letters and frequency — for display on the receiver's LCD or fluorescent output. It can send the name of the artist, album, and song digitally for display. That's a great feature and, with an alphanumeric display, many other items can be displayed.

A station may even have a program guide. Short news briefs, weather, traffic, and even financial information can be transmitted, when appropriate. Of course, if you have digital data transmission capability, there is always the potential to transmit images, such as digital camera-like still images. That remains to be seen.

There are a few downsides to this new system. Aside from the extra cost of a new radio, one potential problem is adjacent channel interference. There may be instances when a station on an adjacent frequency can interfere with the signal that you are trying to pick up. The system has been designed to reduce adjacent channel interference, but, in some high density population areas with many stations, you may occasionally hear some interference.

A second problem is interference from distant AM stations. At night, AM signal propagation changes dramatically. During the day, the sun ionizes the lower layers of the ionosphere, making radio wave refraction such that only short distances are viable. Without the sun, ionized layers appear at a higher level, permitting long range skip propagation; at night, it is often possible to hear AM stations from thousands of miles away.

Such signals could interfere with the station you may be listening to. Again, adjacent channel interference is minimized by the system electronics, but it could still be a problem. Initially, the FCC is permitting IBOC AM operation during the day only.

How It Works

The new digital broadcast radio service is referred to as high definition radio (HD Radio). It is also known by the name given to it by its

inventors — in-band on channel (IBOC) radio — meaning that the new digital system works within the same spectrum and channel assignments that are now used for analog radio.

The creator of this system is Ibiquity Digital Corporation of Columbia, MD. They have been working on this terrestrial digital radio system for years. It was finally blessed by the Federal Communications Commission (FCC) back in October, 2002.

It has taken this long to make commercial equipment available so that broadcast stations can transmit digital signals. It has taken time for radio manufacturers to design and build compatible receivers. As of this year, almost everything is in place for a roll out of this service.

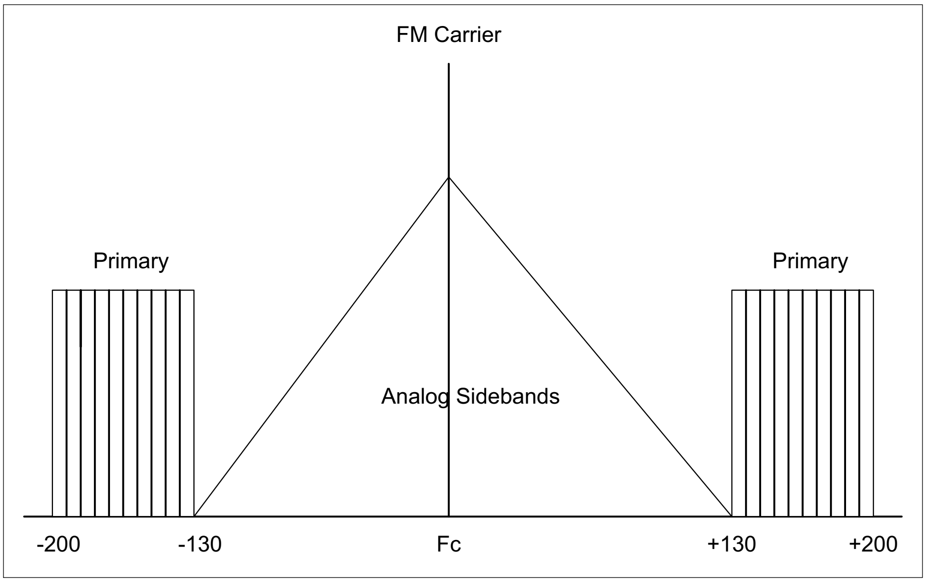
One of the reasons that this service was approved by the FCC is that it is fully compatible with the current analog AM and FM radio services. Each station will continue to broadcast its standard analog signals for listeners with older, traditional radios, but — for between \$70,000.00 and \$100,000.00 — a station can buy the hardware to upgrade to the IBOC system. This system adds the digital transmission in only slightly more than the same spectrum space allocated for analog transmissions. This is called the hybrid mode. It is expected that, over the years, the system will evolve into a fully digital mode, where the analog signal is dropped completely and the entire spectrum is digital.

The digital signals are transmitted as sidebands above and below the analog sidebands. Figure 1 shows the arrangement in the AM band. Normally, AM stations only use 10 kHz of space. With a frequency response of only up to 5 kHz, this makes the sidebands extend out 5 kHz above and below the carrier frequency.

With AM stations usually spaced 10 kHz apart, the FCC usually makes sure that there are no local stations adjacent to one another, in order to prevent interference. This means that the local station is actually permitted to use up to 15 kHz of bandwidth above and below the carrier, giving it the extra space needed to accommodate the digital sidebands.

The same is true in the FM band. Stations are typically spaced 200 kHz apart, but the bandwidth of the signal — with an upper frequency limit of 15 kHz and a modulation index of five — is about 260 kHz. An additional 70 kHz is added above and below the analog sidebands to accommodate the digital sidebands, making the total bandwidth about 400 kHz (Figure 2).

Figure 2. HD Radio FM hybrid spectrum.



As you may know, it takes a great deal of bandwidth to transmit digital signals. Even with efficient modulation methods, digital signals consume a great deal of bandwidth. To reduce the amount of bandwidth needed, audio signals with a frequency range up to 20 kHz are compressed. That is, after the audio signals are digitized by an analog-to-digital converter (ADC), they are put through a mathematical process that reduces the total number of bits needed to accurately represent voice or music.

MP3, for example, is a type of digital audio compression that permits many songs to be stored in flash memory or on a small hard drive in an MP3 player. Another type of compression is used in digital radio. By reducing the overall number of bits, the data rate can be lower and that translates into less bandwidth.

After the data has been compressed, it is scrambled to randomize the bits and to minimize multiple serial 0 or 1 bits that can degrade reception. Next, the scrambled signal is encoded. The encoding process is essentially one of adding extra bits that will be used in a forward error correction (FEC) scheme. Some form of error detection and correction is needed in most digital radio systems in order to overcome the problems that are invariably caused by noise, fading, and interference.

Following the FEC encoding, the digital data is interleaved. This process reorders the serial bits to disperse errors that develop in a fading channel. The interleaved signal is finally sent to the modulator.

As for the modulation method, both the AM and FM systems use orthogonal frequency division multiplexing (OFDM). This extremely complex method spreads the signal over a relatively wide band, which helps to minimize the fading and reflections often encountered in vehicle radios. (*Note to Readers*: Many of you have expressed an interest in learning how OFDM

works; keep reading *Nuts & Volts* for my upcoming column on this topic.)

OFDM has been increasingly adopted for many new wireless applications. For example, it is used in wireless local area networks (WLANs), specifically Wi-Fi IEEE 802.11 a and g standards. OFDM is also the basis for digital subscriber lines (DSL) — the high speed broadband Internet connection offered by many telecom carriers. In DSL, OFDM is better known as discrete multitone (DMT). OFDM is also the modulation of choice for future fixed broadband wireless systems.

OFDM takes the fast, serial digital signal and divides it into multiple, slower, parallel streams of bits that go on to modulate multiple adjacent carriers. In most applications, there are dozens or even hundreds of individual carriers. In the AM IBOC system, there is a total of 82 carriers spread over two sets of sidebands (refer to Figure 1).

There are two sets of digital sidebands — primary and secondary. There are also some tertiary sidebands that operate, as they say, under the analog sidebands, which means in the same spectrum space. These tertiary sidebands do not interfere with the analog sidebands because the carrier phase relationship is quadrature. That is, the analog and digital carriers are 90 degrees out of phase with one another.

There are three sets of 24 upper and 24 lower carriers. The first set — tertiary carriers — is modulated using quadrature phase shift keying (QPSK). Then there is the set of secondary carriers modulated with 16-QAM or 16 level quadrature amplitude modulation. Another set of carriers is in the secondary sidebands and these are modulated with 64-QAM. The individual carrier spacing is 181.7 Hz. All of the digital sidebands are broadcast at a significantly lower power level than the AM analog sidebands, roughly 30 to 40 dB below the main AM carrier level.

A similar arrangement is used in the FM system. Again, refer to Figure 2. These sidebands above and below the analog sidebands are regions which are divided into 10 sectors. Each sector is further divided into 18 subcarriers, each of which will be modulated by some portion of the divided digital data. These carriers are spaced at every 363.373 Hz.

You may be wondering how you generate and modulate all those separate carriers. The answer is that you do it digitally. It is actually a mathematical process that is carried out by a digital signal processor (DSP) chip programmed for this purpose. The process is known as an Inverse Fast Fourier Transform (IFFT).

The DSP chip takes in the serial data signal and uses it to create a composite output waveform that contains all of the desired subcarriers, modulated as desired with the serial data and added together. This signal is then sent to a digital-to-analog converter (DAC) that produces the RF signal to be modulated on to the main station transmitter carrier — mathematical magic.

The IBOC Receiver

Our main interest in all of this is the ability to pick up and enjoy the new digital AM and FM stations. We need a special radio receiver to do this. A general block diagram of a receiver that handles both AM and FM analog, as well as digital signals, is shown in Figure 3. The IF outputs from the tuner are digitized in analog-to-digital converters (ADC), downconverted, and sent to the DSP. The DSP algorithms are stored in the flash memory and the DRAM holds intermediate data. The DSP output is sent to DACs that recreate the analog sound for the two power amplifiers (PA) and speakers. An embedded microcontroller operates everything else and accepts inputs from the push buttons and controls and generates the display.

The antenna feeds into a tuner that amplifies the incoming signals (both 530 to 1,710 kHz for AM and 88 to 108 MHz for FM) and downconverts them to an intermediate frequency (IF), as in any superheterodyne receiver. The IF is typically 455 kHz for AM and 10.7 MHz for FM, as it is in many analog receivers. From there, the IF signals are sent to a converter chip, where they are digitized, digitally downconverted to a lower frequency, and sent to the separate DSP.

A radio that implements most of its functions in software that is run by a DSP is called a software defined radio (SDR). As A/D converters and the DSP chips themselves get faster, higher frequencies and faster data rates can be handled. The ultimate SDR is one in which the antenna is connected directly into the A/D converter and then *all* of the radio functions — filtering, mixing, demodulation, and so on — are done in software. Today, we are more than halfway there.

The main source of the DSP chips for HD Radio is semiconductor giant, Texas Instruments. Their popular TMS320C6000 line of DSP

The Other Digital Radio

The oldest digital broadcast radio is known as Digital Audio Broadcasting (DAB), which uses what is called the Eureka 147 system. DAB first came online in Europe and Canada in 1995. It is also available in some parts of Asia.

This system uses either the 174 to 230 MHz VHF band or the 1,452 to 1,490 MHz microwave L-band. There are dozens of receiver manufacturers. The adoption rate is already over 70% in England, Denmark, and Germany and adoption in the other European countries is growing. Canada recently started using DAB and adoption is already over 35%. Adoption is already nearly 100% in Taiwan and Singapore.

A similar system — known as Digital Multimedia Broadcast (DMB) — is also growing in Korea and Japan. The bottom line here is that the US is way behind the rest of the world, but is about to catch up with HD Radio, starting this year. Stay tuned.

chips has been programmed and customized to perform all of the needed DSP functions for HD Radio. The most recent version is called the TI TMS320DRI250. The DSP chip handles all of the filtering, error detection and correction, demodulation, de-interleaving, and other stuff. The demodulation process uses the fast Fourier transform (FFT).

The final decoding and decompression produces the original serial digital audio at the standard 44.1 kHz CD rate. This signal then goes back to the converter chip, where it is translated back to analog into two DACs and sent to the external stereo audio power amplifiers.

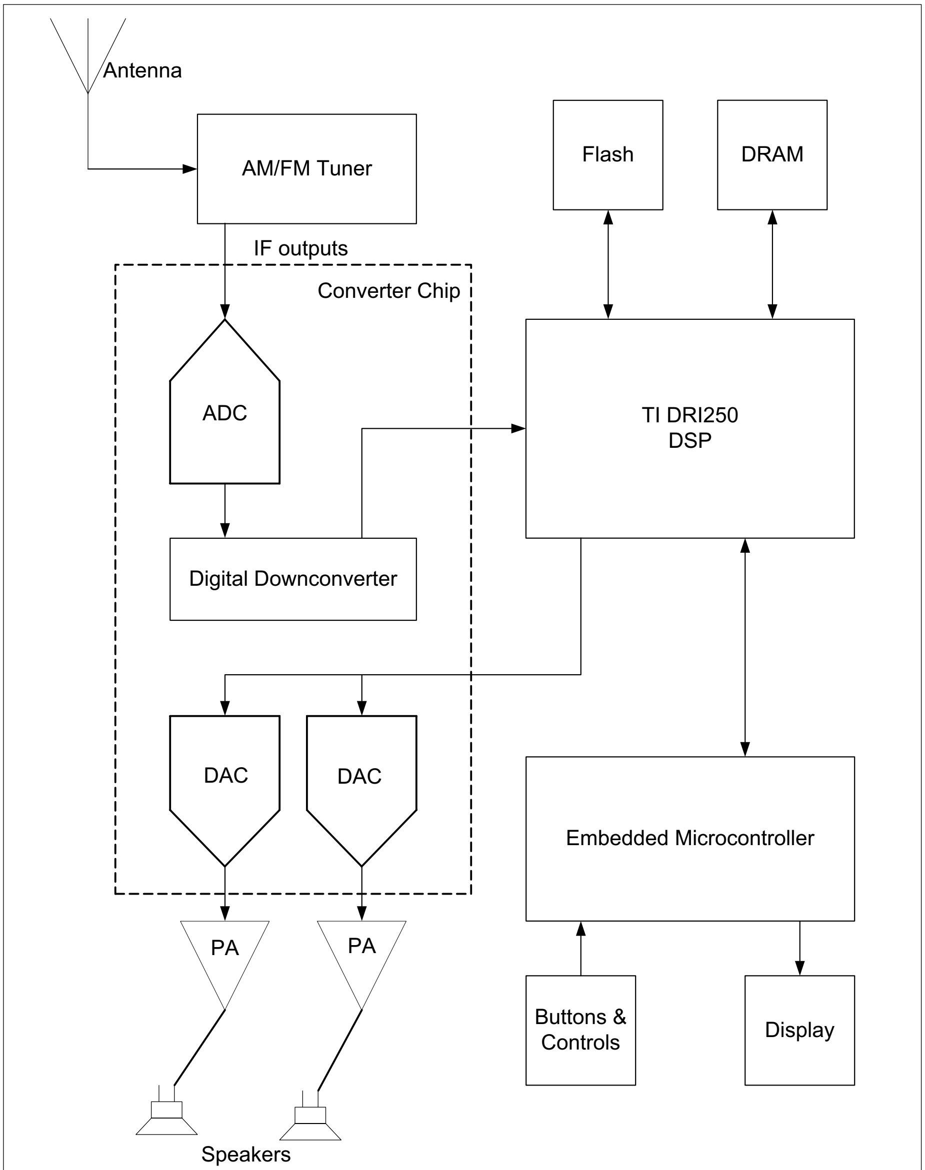
What's Available Now?

As of the first of the year, over 300 stations have signed up for HD Radio licenses. Only about 70 are currently on the air. The majority of major cities have at least one station in operation; most of these are FM stations. Also, HD Radio receivers — primarily car radios — are available. Kenwood was the first on the market, but Panasonic, JVC, and Harmon Cardon will also have units available soon. You can get these receivers at Best Buy, Circuit City, and a few other electronic stores.

As for the impact of HD Radio on standard analog AM and FM, as well as the newer digital satellite services, that remains to be seen. The plan is for HD Radio to eventually evolve into the all digital mode. Progress will, no doubt, be made, but the evolution will take time. Look how long it is taking for HDTV — which has been around for years — to come online. Will it ever replace regular TV?

HD Radio will certainly be a source of concern for the newer satellite radio services, like Sirius and XM. Because it is free (excluding the cost of a new receiver), it will get lots of attention. Yet, it will take years before many stations are available. Of course, both Sirius and XM offer 100 channels of music, talk, news, sports, and more right now, but for a subscription price. Both of those services are available continuously across the US, where AM and FM stations are strictly local, fading in and out as you travel. It looks to me like we will have lots of options over the the coming years, as all of these services continue to serve their niches. **NV**

Figure 3. A general block diagram of an HD Radio receiver.



Useful Websites

If you are looking for more in-depth information on HD Radio, check into these sites:

Ibiquity Digital Corporation
www.ibiquity.com

National Association of Broadcasters
www.nab.org

National Radio Systems Committee
www.nrscstandards.org

RadioScape Ltd.
(Eureka 147 DAB DSP software)
www.radioscape.com

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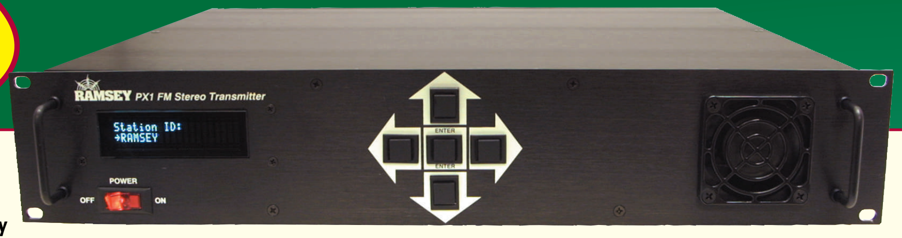

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PX1 circuitry makes subtle adjustments to various circuit parameters depending upon frequency, temperature, power, audio level, and deviation - in short, it's like having a station engineer constantly monitoring and adjusting on-the-fly! An 8 times oversampled stereo generator with true analog filters throughout assures a clean, refreshing sound image while the RF transmitter chain employs generously rated components for headache-free, long life. The PX1 can also be used as a stand-alone exciter for higher power installations.

EASY INSTALLATION, QUICK SETUP, SIMPLE CONNECTIONS!
Installation of the PX1 is a breeze. A standard Type-N connection is provided for RF Output. Balanced (XLR) left and right audio inputs are provided to properly interface with any source you have. In addition, BNC SCA/Digital inputs are provided along with a quick disconnect connector for a 12 VDC standby/back-up power input. In short, connect your audio sources and antenna, power it up, set frequency and power, and you're on the air! It doesn't get any simpler! All of this in a compact 3.5" standard 2 rack unit case.

EXTREMELY VERSATILE, FOR ANY APPLICATION!
Although specifically designed for Domestic LPFM and International stand-alone stations, the PX1's compact size and 12VDC operation make it ideal for a backup transmitter at a commercial station, or as a low power translator station.

FULL FRONT PANEL MONITORING
Operation of the PX1 is simple and intuitive via the front panel switch matrix. All functions, controls, and status are displayed on the 2 line by 20 character vacuum fluorescent display. *(Note: The end user is responsible for complying with all FCC Rules & Regulations within the US, or any regulations of their respective governing body).*

PX1 **Professional 35 Watt Synthesized FM Stereo Transmitter** **WOW!! SAVE $300!** **$1495.95** ~~$1795.00~~

35 Watt Complete FM Stereo "Station In-A-Box"

- ✔ 35 watt FM stereo transmitter
- ✔ Integrated CD player
- ✔ Integrated cassette player
- ✔ Integrated audio mixer
- ✔ Professional microphone and cables
- ✔ Omnidirectional antenna and coax
- ✔ Installed and prewired in a high impact road case!

Get On The Air Quick With The All-In-One Solution!

YOU ASKED FOR IT!
One of the most requested FM broadcast products over the past year has been a "radio station in a box". At first we laughed. What did they mean... in a box? Then as the requests came pouring in, we found out! Overseas customers, as well as some of the new LPFM licensees have a need to quickly "get on the air" at temporary locations or in the interim to their installed studio/transmitter setup. A number of overseas customers also had to originate short term programming from various remote origination sites for disaster preparedness broadcasts! Well, here you go... a radio station in a box!

EVERYTHING IS INCLUDED!
First we took our state of the art PX1 FM Stereo Transmitter and installed it in an impact resistant, rack mount travel case. Then we added the Superscope PAC750 integrated mixer/cassette deck/CD deck. We prewired them, then added a professional microphone and some cables. Finally, we included our 3.4 dB gain omnidirectional FM Broadcast antenna with 100 feet of matching low loss coaxial cable. There you go, a complete radio station, ready to plug in, and be on the air! Just imagine: Show up, open up the case, plug in the AC power, temporarily mount the antenna, connect the coax, and you're all set! The applications are endless! From live remotes to station backup transmitters, our "Station In A Box" is your solution! *(Note: The end user is responsible for complying with all FCC Rules & Regulations within the US, or any regulations of their respective governing body).*

PX1 FM STEREO TRANSMITTER
Complete 35 Watt Synthesized FM Stereo transmitter. Full featured digital display of all operating parameters and easy to operate.

PAC750 INTEGRATED AUDIO SYSTEM
A complete, integrated, professional audio system. Includes an input audio mixer, cassette deck, CD player, with full audio and cueing controls.

FMA200 OMNIDIRECTIONAL VERTICAL ANTENNA
This 5/8 Wave omnidirectional antenna gives you 3.4 dB gain over a unity gain antenna. That's more than twice the effective radiated power. That will give you the maximum punch from your temporary location. Quick, on-the-spot assembly specifically for your operating frequency. Easy to mount on any mast, tower, or building.

Some customers have even mounted them on the roof of their van, and have operated the station from inside the van! If you're setting up a temporary station this is ideal!

We also include 100 feet of low loss LMR-400 coaxial cable, with connectors pre-installed to get you on the air quick. Just plug it in at both ends!

PROFESSIONAL MICROPHONE, STAND, AND CABLES
Professional handheld dynamic microphone, 25' professional XLR microphone cable, and a matching desk stand.

PXB35 **Professional 35W FM Stereo Station In A Box** **WOW!! Get On The Air QUICK** **SAVE $500!** **$3295.95** ~~$3795.00~~

AM & FM Broadcast Kits
Have Fun And Save $$!

Professional FM Stereo Radio Station

✔ Synthesized 88-108 MHz with no drift
✔ Built-in mixer - 2 line inputs, 1 mic input
✔ Line level monitor output
✔ High power version available for export use

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

FM100B	**Super-Pro FM Stereo Radio Station Kit**	$259.95	~~$269.95~~
FM100BEX	**1 Watt, Export Version, Kit**	$329.95	~~$349.95~~
FM100BWT	**1 Watt, Export Version, Wired & Tested**	$399.95	~~$429.95~~

WOW!! SAVE!!

Professional 40 Watt Power Amplifier

✔ Frequency range 87.5 to 108 MHz
✔ Variable 1 to 40 watt power output
✔ Selectable 1W or 5W drive

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 40 watts! And this is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

PA100	**40 Watt FM Power Amplifier, Assembled & Tested**	$549.95	~~$599.95~~

WOW!! SAVE!!

Synthesized Stereo FM Transmitter

✔ Fully synthesized 88-108 MHz for no drift
✔ Line level inputs and output
✔ All new design, using SMT technology

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	$119.95	~~$139.95~~

WOW!! SAVE!!

Tunable FM Stereo Transmitter

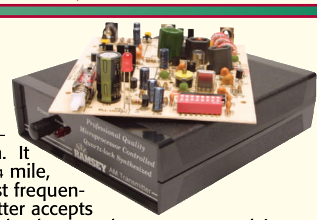
✔ Tunable throughout the FM band, 88-108 MHz
✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	$39.95	~~$44.95~~
FMAC	**110VAC Power Supply for FM10A**		$9.95

WOW!! SAVE!!

Professional Synthesized AM Transmitter



✔ Fully frequency synthesized, no frequency drift!
✔ Ideal for schools
✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	**Professional Synthesized AM Transmitter Kit**	$89.95	~~$99.95~~

WOW!! SAVE!!

Tunable AM Transmitter

✔ Tunes the entire 550-1600 KHz AM band
✔ 100 mW output, operates on 9-12 VDC
✔ Line level input with RCA connector

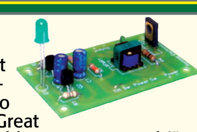
A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	**Tunable AM Radio Transmitter Kit**	$29.95	~~$34.95~~
AC125	**110VAC Power Supply for AM1**		$9.95

WOW!! SAVE!!

Mini-Kits...
Great Starters!

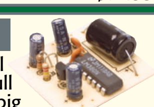
Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4	**Tickle Stick Kit**	**$12.95**

Super Snoop Amplifier



Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

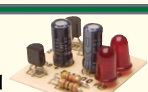
BN9	**Super Snoop Amp Kit**	**$9.95**

Dripping Faucet

Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

EDF1	**Dripping Faucet Kit**	**$9.95**

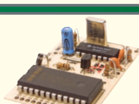
LED Blinky



Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1	**LED Blinky Kit**	**$7.95**

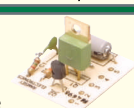
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7	**DTMF Decoder Kit**	**$24.95**

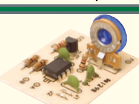
Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3	**Electronic Siren Kit**	**$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5	**Universal Timer Kit**	**$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1	**Voice Switch Kit**	**$9.95**

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1	**Encoder/Decoder Kit**	**$9.95**

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Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

A solar primer, of sorts. New parts in my designs and where to get them. Subwoofer filter, revisited. Circuits: car vibrator, IR stuff, interfacing a PC to A/V, and a popular power amplifier chip explained. Finally, when not to plug your TV into the AC outlet.

Photovoltaics Basics

Q. I have five solar panels (surplus supplies) that I would like to get some use out of. The panels — SX-120s from BP Solar — have an operating voltage of 33.7 volts at 3.5 amps and are rated at 120 watts. I had planned to connect the panels in parallel to charge a 24-volt battery array. The array would consist of two 12-volt batteries, in series, so that I can tap into the bank to obtain both 24 volts and 12 volts, which I will use to power outdoor lighting and a remote work shed. Inside the shed, I also want to get a DC to AC inverter for indoor lighting and possibly at least one AC outlet. Because of zoning codes, the wiring between the two buildings has to be low voltage. I thought I could do the photovoltaics myself, but have since discovered that I need a lot of help. Help!

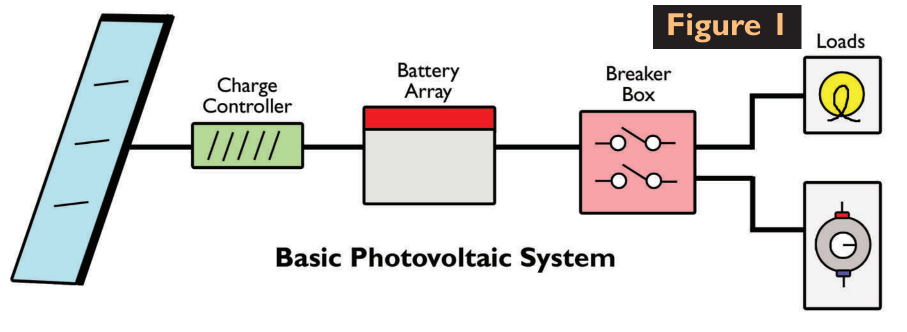
Art
via Internet

A. This is a tall order for a column with limited space, but I'll try my best to answer it. First, you have the right approach by having these particular panels charge a 24-volt battery bank (Figure 1). The building blocks include the solar panels, batteries, charge controller, breaker box, and your load (lights, etc.). The voltage of the solar panels has to be matched to the charging profile of the battery, which you have in hand. That is, you can't charge a 24-volt battery with a 12-volt panel.

The second major block is the storage batteries, which provide electricity when there is no sun. Let's say the sun shines six hours per day and you want to be able to use that energy 24/7. Here's where it gets sticky. You want enough battery capacity to serve your worst-case scenario, but you don't want to spend money on capacity (extra batteries) that you'll never use. So, you need to balance the space for the batteries and their expense with your needs. A rule of thumb is to multiply your load requirements (in amp-hours) by four to arrive at the needed battery capacity. For example, if you require four amps each day for four hours, your amp-hour need is 16 AH, which means you need a 64 AH battery.

Between the photovoltaics and batteries is a charge controller — basically, a voltage regulator. It prevents the solar panels from overcharging the batteries. The charge controller can take many forms, including series linear, series switching, or shunt. Which one you use depends on your situation

Figure 1



Basic Photovoltaic System

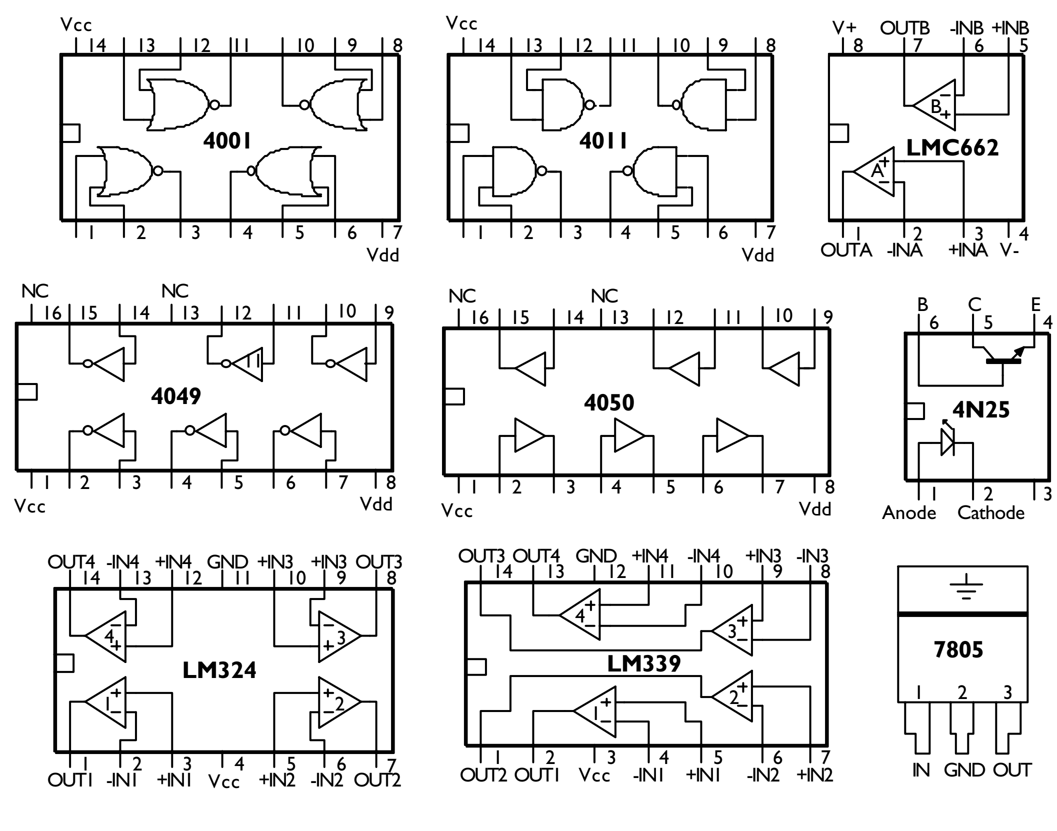
and what you want to do with the excess solar energy produced when it's not being channeled to the load and batteries.

The last item is the load, which can take on an infinite number of configurations. A breaker box will be recommended for the distribution of the power and for overload protection (mostly for fire protection).

As for tapping into the battery array for both 12-volt and 24-volt sourcing, I'm not so sure you can do that. You're going to have a hard time balancing out the loads, even in a three-wire system. One battery will always have more usage than the other. I suggest you run the system at 24 volts and use buck switching voltage regulators at the loads that need 12 volts. Another benefit of using a 24-volt system is that the wiring resistance loss is considerably less, enabling you to run thinner wires between your batteries and your work shed.

Yes, I know you readers would have me elaborate on this very simple answer to a complex problem, so I'm expecting your questions and will meter them out, as space permits. In other words, stay tuned.

Figure 2



Pinout Chart

Q. In the January 2004 issue, you specify an LMC662 op-amp for the "Capacitor ESR Tester." I can't find this device in any substitution book or on the Internet.

Also, for the "Scope Calibration," the upper right IC shows four leads attached when, in fact, the data sheet in the transistor substitution manual shows only three leads coming out of this gate. Please clarify.

Frank Petrich
Orland Park, Il

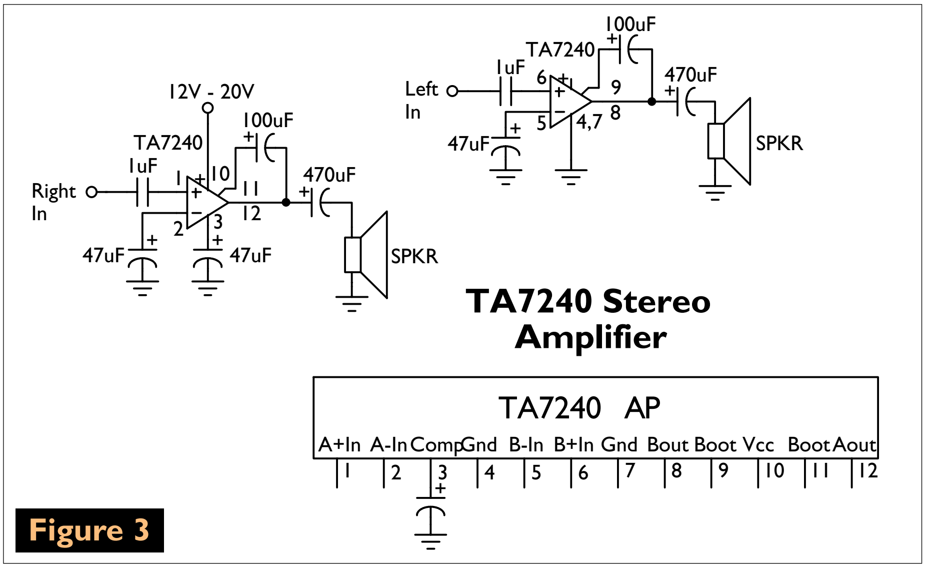
A. The parts I use in my circuits are all available (with very few exceptions) from Digi-Key (800-344-4539; **www.digi-key.com**). Digi-Key has no minimum order, but they do charge a $5.00 handling fee for orders under $25.00.

As for the LMC662 op amp, I've just started using it in my designs in place of the 741 or LF353 because it has a rail-to-rail voltage output swing, lower input offset, and lower voltage functionality. In other words, it's a superior, low-cost op-amp that's pin compatible with the popular LM358 and readily available from many sources.

Regarding the extra pin on the 4001 gate, notice that it's coming off the top of the gate and connected to the five-volt output of the 78L05 voltage regulator. This should indicate that it's the V_{CC} input (pin 14). You may also notice that I don't number the pins of the gates. I do this on purpose. If I were to number the pins of a gate, it would clutter the drawing and lock you into a wiring pattern. By not designating pin numbers, you are free to move the gates about to satisfy your layout. I know this can get confusing, so let me give you a chart of the pinouts of the ICs I use most in my designs (Figure 2). Make a copy of this chart and tape it to your workshop wall for easy reference. (*A PDF version of this chart can be downloaded from our website,* **www.nutsvolts.com** *under the name PINOUTS.PDF — Editor Dan.*)

Terminating Unused Gates

Q. In Figure 10A of the January 2004 issue, you show two 4069 gates just left hanging in the air. Is



TA7240 Stereo Amplifier

Figure 3

part of the schematic missing?

Pam Miller
via Internet

A. No, that was done on purpose to remind the reader that all unused gates must have their inputs tied high to prevent unwanted oscillation. Last time I didn't mention this, I got a flood of letters. So, I figured a picture is worth a thousand words. It looks like I'm going to have to find a happy middle ground between text and schematic. I really hate repeating what to do with unused inputs in every column, so suggestions are welcome.

TA7240 Power Amp

Q. I have several TA7240AP amplifiers that I want to experiment with in a multi-channel amplifier. Unfortunately, I have no electrical diagram to show me how to connect the TA7240. Can you help me?

Nicholas
via Internet

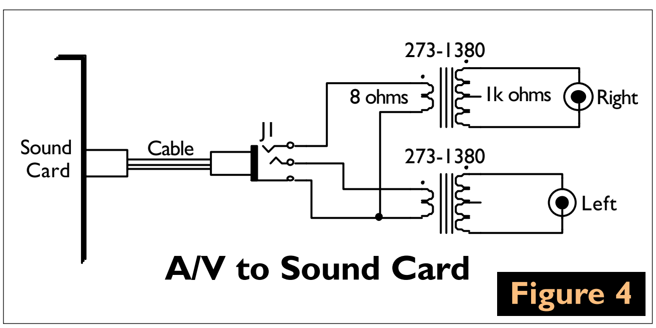
A. The TA7240 is a very popular chip overseas and can be purchased from Donberg Electronics (**www.donberg.ie**) for about $6.00. The chip contains two power amps housed in a single, 12-pin plastic package with integral heatsink and is electrically equivalent to the KA2211. The Pinout and typical application of the TA7240 is shown in Figure 3.

Sound Card to A/V

Q. I would like to hook up the audio out from my computer's sound card to my stereo and TV. Unfortunately, to do this I have to turn the volume on the sound card all the way up to get a reasonable sound level from my stereo or TV. Moreover, there is an audible hum that is impossible to live with. Right now, the connection is only between my computer and TV, but I would like to split the audio to my stereo so that I do not have to turn on the TV to listen to CDs. My stereo and TV both have RCA audio inputs. Any solutions?

Robert G. Blazej
UC Berkeley, CA

A. You have an impedance mismatch. The sound card has a 32 Ω output to match the impedance of a typical headset. On the other hand, your A/V equipment is expecting a 10K input impedance. A not so perfect, but easy, solution is to insert an audio output transformer between the two. RadioShack sells one (273-1380) for $2.99. You'll need two: one for the left channel and another for the right channel. Here's how to wire them (Figure 4).



A/V to Sound Card

Figure 4

Subwoofer Filter Revisited

Q. Concerning the subwoofer filter circuit in the September 2003 issue, I have two questions:

1. Can the input be modified to accept the R and L outputs from a computer sound card? I want to add a subwoofer to my computer sound system.

2. It wasn't clear, but I believe the filter circuit output shown drives a speaker directly. If so, a preamp out version would need to feed a subwoofer amp. Right? I could use a small (5 W) IC amp to drive the subwoofer adequately for the low level listening on my computer.

R. C. Siebers
Woodbury, MN

A. A lot of readers had questions about that circuit (see the Mailbag), so let me try again. The original question asked for a low-impedance input to a high-impedance auxiliary amplifier. The input from the speakers was not 100 watts, but rather earphone volume, and the output isn't capable of driving a subwoofer speaker directly. It needs a power amplifier of five watts or better. Figure 5, which is built around the orignial subwoofer,

shows a subwoofer design for PC use.

The first section is the identical low-pass filter, with the addition of a second 220K input resistor and an upgrade to the superior LM662 op amp. The output is an LM383 power amplifier capable of outputting eight watts into a 4 Ω load. That's it. The amplifier plugs into the Line Out of the sound card (a stereo Y adapter from RadioShack is required) and should be loud enough to match the volume of a pair of amplified PC speakers.

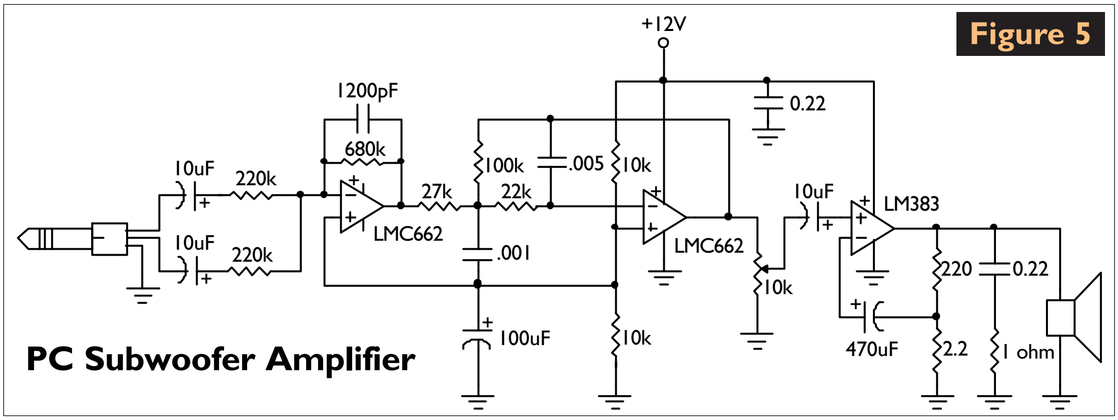


Figure 5

PC Subwoofer Amplifier

Looking for Tube Audio Equipment

Q. Do you know of someplace where I can get a tube pre-amp/amplifier? I would prefer a kit or rebuilt unit. It would be for my home audio use.

Dabney Tolson
Lake St. Louis, MO

A. I cut my baby teeth on a DynaKit and still remember fondly the smell of solder rosin in the morning (which may explain that weird twitch I have). Seriously, I know there are still some tube amps — even some kits — around, but they're hard to find at a reasonable price. I know that many of our readers can help you better than I can and I ask for their help. In the meantime, let me give you a few places to start:

www.audiotubes.com/amps.htm
http://audionova.nu/innehall/tube_kits.htm

www.worldaudiodesign.co.uk

Car Radio Vibrator

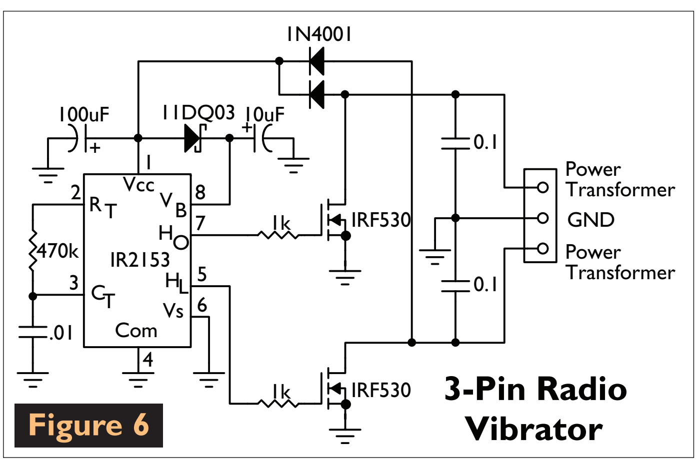
Q. By any chance, do you have a circuit for replacing the vibrator in antique car radios? I'm interested in both positive and negative ground applications. I'm not interested in buying a plug-in version for $40.00.

Carl
via Internet

A. It just so happens that I was working on a design for a 12-volt, three-pin vibrator replacement for a reader a couple of years ago. Unfortunately, he passed away before I finished it and, out of respect for his family, I put it on the shelf. Your request has renewed my interest in this project and here are the end results. Figure 6 shows the vibrator replacement itself and Figure 7 shows how it plugs into a typical tube-type car radio; the Xs indicate the vibrator pins.

IR Remote

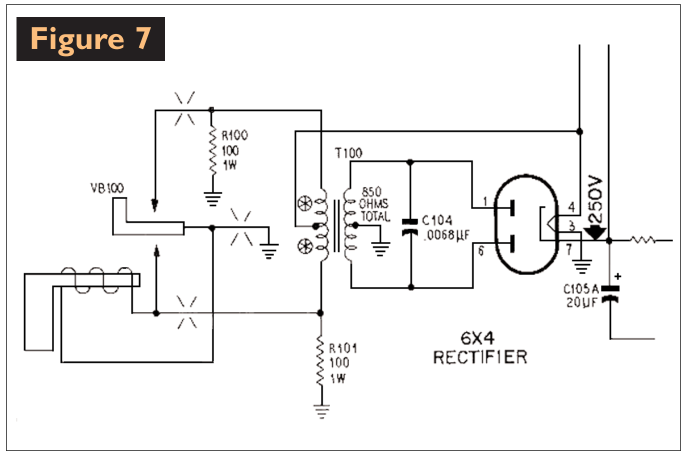
Q. I recently constructed an IR remote unit which used a Stamp II microcontroller for a project. This unit uses the principles of pulse-width modulation (PWM), with each button producing a pulse of different duration on an infrared LED. I am using a phototransistor to pick up this signal, but I'm having a problem with the ambient light in the room. The room light saturates the phototransistor to a point where the infrared signal is indiscernible. Is there some kind of material that I

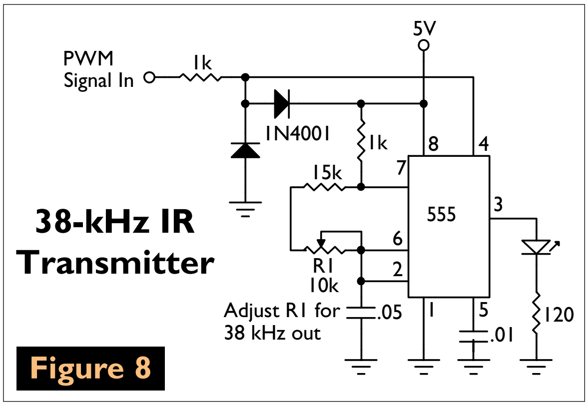


3-Pin Radio Vibrator

Figure 6

Figure 7





38-kHz IR Transmitter

Figure 8

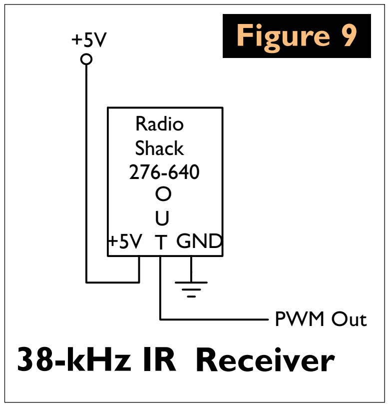


Figure 9

38-kHz IR Receiver

can use to cover the phototransistor that will block visible light, but allow infrared light to pass?

Frank
via Internet

A. This is a common problem and one that takes more than one action to cure. Believe it or not, I've had good luck using a RadioShack construction box (like the 270-283). For reasons that aren't clear to me, this black box blocks ambient light, yet lets IR pass. Unfortunately, it doesn't do this well, so the sensitivity of your receiver is cut in half; it also doesn't work with unmodulated IR.

A better solution is to use a carrier frequency modulated with your data stream — or, in your case, your PWM generator. (In case you don't have an IR transmitter yet, you can use the circuit in Figure 8.) By using a carrier, you can easily filter out the unwanted ambient light, while increasing the sensitivity to your signal. Rather than reinvent the wheel, I suggest using a commercial IR receiver, like the RadioShack 276-640 (Figure 9). This module has a built-in elliptical lens that helps to block light noise from above and below the center frequency of 38 kHz.

Simple Dipole TV Antenna

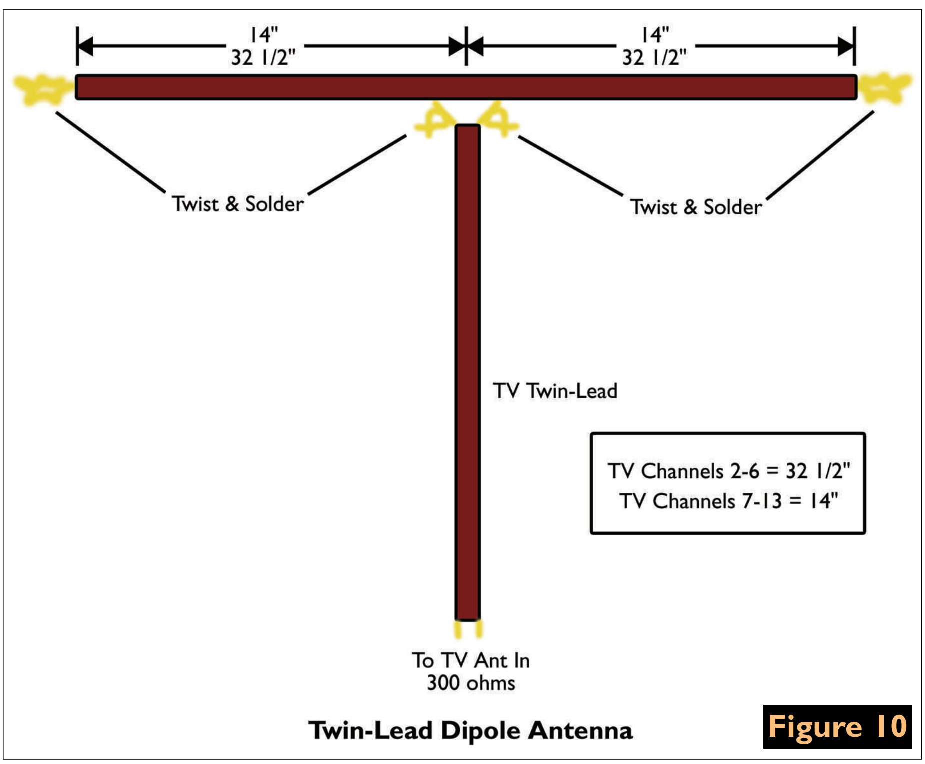
Q. Several years back, you published a diagram of a radio antenna that used a phone's wiring. How about publishing a diagram for using AC house wiring to improve TV reception (UHF/VHF)? When it's windy outside, my roof antenna gyrates and I would rather use my inside AC wiring as a TV antenna for better reception.

Mike
via Internet

A. Not really. The problem is that the configuration and lengths of the wires in your house are not matched to the wavelengths of TV signals. The impedance of this "antenna" is poorly matched to your TV's input and the directivity (the lobe pattern) is undefined. In other words, some stations may come in okay, while others may not come in at all or suffer from ghosting.

Furthermore, electric motors (especially small appliances), fluorescent lights, and light dimmers will generate noise on the electric wiring and will likely cause streaks or snow in the picture. However, if you care to try it, you can buy the ClearVue Antenna Booster (**www.alltvstuff.com/vue1.html**) for about $20.00 — the cost of a decent pair of rabbit ears.

A better solution to your problem is a dipole antenna (Figure 10) that you can hang on the wall or install in the attic. The antenna is made from a length of twin-lead antenna cable — the flat kind that's often used for outside antenna downleads. The dipole consists of two equal lengths of twin-lead that are placed horizontal to the ground.



Twin-Lead Dipole Antenna

Figure 10

The dipoles connect to a downlead that connects to the 300 Ω input of your TV set. The length of the dipoles is frequency sensitive and changes from channel to channel. The lengths for the two VHF bands

are: channels 2-6 and channels 7-13 — the length of the download isn't critical. If you decide to put it in your attic, I suggest using PVC water pipe as a form for holding the shape of the antenna. The pipe will also let you rotate the antenna for maximum signal strength.

Whether you use the house wiring or twin-lead dipole, I'm assuming you don't live in a building with concrete walls or a metal skeleton (many commercial buildings and an increasing number of residential structures use galvanized steel studs rather than wooden two-by-fours). If you live in a building with metal in the wall, only an outdoor antenna will work.

WARNING: Under no circumstances should you attempt to directly connect the household electric wiring to the antenna terminals of a TV or VCR. If you do, you risk damage to the equipment, fire, and/or electrical shock.

DisplayMate Monitor Diagnostics

Q. I'm looking forward to retiring and would like to spend my time fixing things like PC monitors. To get a raster, though, you have to hook it up to a computer. Is there something that you can plug the monitor into to test it, other than the computer? Can it be made?

Joe
via Internet

A. I guess I could design a circuit for you, but it would require a signal generator, power supply, and compatible connectors.

Even then, all you're going to get is a raster. What I recommend is obtaining an old PC — even a 286 will work (you can buy them every day on eBay for a song) — then get a copy of DisplayMate software (**www.displaymate.com/demos.html**). DisplayMate not only provides a raster, but also gives you test patterns that actually troubleshoot the monitor.

Moreover, the software isn't limited to troubleshooting and repair. PC users can use it, too, to fine tune their screens.

Reader feedback: Thanks! This is perfect. It works perfectly on an old notebook PC I had laying around, making it a portable test instrument.

— Joe

MAILBAG

Dear TJ,

Regarding the "Subwoofer Filter" circuit in the September 2003 issue, thanks very much. It was exactly what I was looking for. I look forward to reading your column every month.

Stan
via Internet

Dear TJ,

I agree with the September 2003 comment on the "Subwoofer Filter."

1. The capacitors will degrade the channel separation at high frequencies.
2. In general, amplifiers don't like a heavy capacitor load. It could cause some amplifiers to oscillate and maybe even burn out. The suggested resistor will fix this problem.
3. The 195-Hz low-pass filter's first stage will saturate at low levels if the inputs are from the stereo speakers. Either the inputs could come from the stereo preamp or the speaker signal could be attenuated. It would help a little to reduce the gain of this stage from 3.1 to 1.
4. I did not look at the second stage design.

Bruce
via Internet

Dear TJ,

I noticed in the January 2004 issue that you responded to someone about the Futurlec PC board service. I found that the 20 cents per inch rate is not correct unless a large amount of boards is being made. I found a board house — Custom PCB (**www.custompcb.com**) — that will sell you two 4" x 5.5" single-sided boards — with or without silk-screen and solder mask — for only $9.00 each, plus shipping of about $8.00.

If your layout can be laid out in an array, they will offer to do the work themselves and array your tiny PC board onto a larger board, providing you with more than two, although they only charge for the two boards (plus a charge for cutting each board). They will work directly from your board file (not Gerber) for Eagle, Protel, and Orcad.

Rich Merhar
via Internet

***Response**: The Futurlec pricing is correct. I use them all the time for my prototypes.*

— TJ

Cool Websites!

A definitive discussion on PC power supplies:

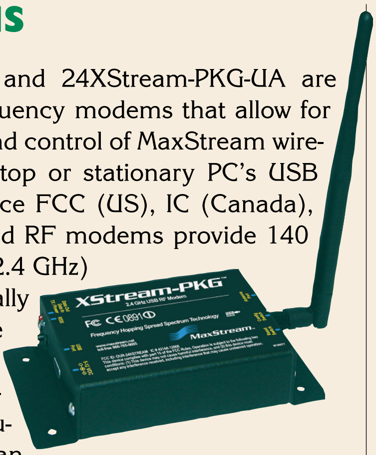
http://nl.internet.com/ct.html?rtr=on&s=1,ogg,1,fyf8,1402,3qmh,cu1s

A computer's BIOS will produce a series of beeps when it finds a failure in the system. Use this quick reference to decode the beeps of two common BIOS systems: AMI and Phoenix.

http://nl.internet.com/ct.html?rtr=on&s=1,ogg,1,4irw,kcyt,3qmh,cu1s

USB RF MODEMS

The 9XStream-PKG-UA and 24XStream-PKG-UA are USB-enabled radio frequency modems that allow for quick testing, monitoring, and control of MaxStream wireless systems through a laptop or stationary PC's USB port. These high-performance FCC (US), IC (Canada), and ETSI (Europe) approved RF modems provide 140 mW (900 MHz) or 50 mW (2.4 GHz) of power output and are ideally suited for remote and mobile applications. They boast up to -110 dBm receiver sensitivity, providing long communication ranges. Users can receive 900 MHz transmissions for up to 1,500 feet (457 m) in an urban environment, up to seven miles (11 km) line-of-sight, and up to 20 miles (32 km) with a high-gain antenna. These RF modems utilize frequency hopping, spread spectrum technology in peer-to-peer, point-to-point, point-to-multipoint, and multi-drop networking configurations. These RF modems list at $250.00 US (900 MHz) and $199.00 US (2.4 GHz) with volume discounts available.



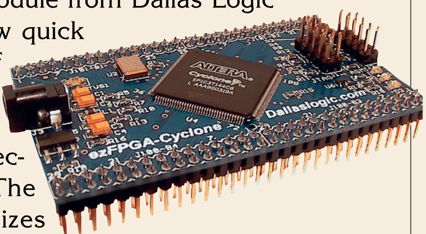
For more information, contact:

MAXSTREAM, INC.
355 S. 520 W. Ste. 180
Lindon, UT 84042
Tel: **801-765-9885**
Email: **info@maxstream.net**
Web: **www.maxstream.net**

Circle #117 on the Reader Service Card.

MODULE ENABLES QUICK FPGA DESIGN AND PROTOTYPING

The new ezFPGA module from Dallas Logic is designed to allow quick implementation of FPGA based digital designs by professional designers, as well as electronics enthusiasts. The ezFPGA module utilizes Altera's latest low cost EP1C3 Cyclone FPGA and Quartus II development software. The 1.7 x 3.0 inch module provides all basic support circuits and 95 general purpose FPGA I/O on header pins. It is ready to be programmed with an end user application. The complete kit includes a Quartus II Starter Suite CD, 5 V power supply, and Altera Byte Blaster FPGA programmer. User manual, schematic, and FPGA starter design are available for download from the Dallas Logic website.



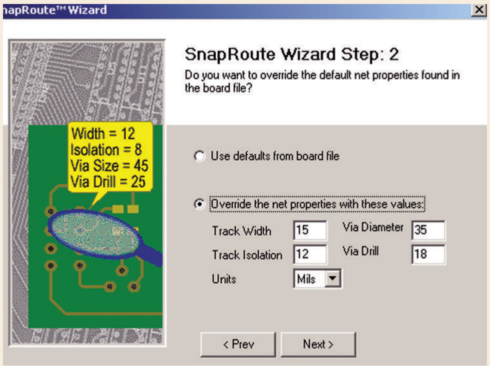
Complete kits are available for online purchasing at $159.00. Individual ezFPGA modules are $99.00.

For more information, contact:

DALLAS LOGIC CORP.
2300 McDermott Rd. #200-305
Plano, TX 75025
Tel: **972-359-2953**
Web: **www.dallaslogic.com**

Circle #140 on the Reader Service Card.

SNAPROUTE™ PCB AUTO-ROUTING SERVICE



Ivex Design International has announced SnapRoute, the new, fully functional auto-routing service for printed circuit board layout (PCB) using WinBoard® PCB. It utilizes the power of auto-router servers via the Internet for results at a high speed and low cost.

SnapRoute allows the user to configure their routing preferences using an easy-to-follow Wizard-based interface that prompts the user for specific information needed to properly route the board, including default or override settings, protecting or deleting existing routes, 45° or 90° track bending, layer naming, power pane allowance, and selecting SMD routing styles.

SnapRoute Specifics

- User-configurable preferences using Wizard-style menus.
- Routes on all available layers simultaneously — not limited to pairs of layers.
- Board sizes up to 80 inches by 80 inches.
- Utilizes via-sharing and other techniques whenever possible to create the fewest number of vias, resulting in reduced production costs.
- Targeted at boards up to four signal layers and 3,500 pins.
- Runs on Windows 95, 98, 98SE, Me, 2000, XP Home, and XP Professional.

Internet and Security

Although the SnapRoute server is used to route the board, access is controlled through unique registration

security codes. No one can see or access your boards or design documentation because your board files are kept locally on your own computer. The only thing that leaves your computer is information about the locations of pins that need to be connected — not the pins themselves.

Introduction and Pricing

SnapRoute is priced, monthly, according to the maximum number of pins on a board, at $9.99 (up to 220); $19.99 (up to 650), and $29.99 (up to 3,500).

Annual service agreements are also available. Service for boards above 3,500 pins will be available at a later date. There are no limits on the number of times you can use SnapRoute during the service period. For a limited time, you can download the SnapRoute software and try the service for free. Activation requires an active Internet connection and a valid WinBoard registration number.

For more information, contact:

IVEX DESIGN INTERNATIONAL, INC.
PO Box 7156
Beaverton, OR 97007
Tel: **503-531-3555** Fax: **503-848-7552**
Web: **www.ivex.com**

Circle #146 on the Reader Service Card.

LED CHECKER

This LED tester is simple to build and use. It tests the blue and white LEDs that require 3.1 to 3.6 volts, as shown in the picture. You get the case, label, test socket, resistor, and 9 volt battery clip, plus instructions. Order online at the HomeNet website under the category, Test Equipment. The LED Checker Plus is $8.95 in kit form and requires $3.00 shipping and handling (USPS for US shipments). Email for other shipping arrangements.

For more information, contact:

HOME NET
13246 Quincy St. NE
Blaine, MN 55434
Fax: **763-755-9661**
Email: **homenet@mninter.net**
Web: **www.homenetsales.net**

Circle #134 on the Reader Service Card.

Circle #30 on the Reader Service Card.

Selected Titles for the Electronics Hobbyist and Technician—

The *Nuts & Volts* Hobbyist Bookstore

Robotics

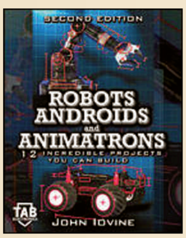
SUMO BOT
by Myke Predko / Ben Wirz

Here's a fun and affordable way for hobbyists to take their robot building skills to the next level and be part of the hottest new craze in amateur robotics: Sumo competition.

Great for ages 14+, the kit comes complete with:

- Pre-assembled PCB
- Multi-function, dual-channel remote control
- Robot hardware, including collision-sensing infrared LED and receivers
- CD-ROM with programming instructions and file chapters of robot building tips and tricks
- A built-in Parallax BASIC Stamp 2 and prototyping area, allowing hobbyists to create their own robot applications without having to purchase additional Parallax products **$99.95**

Robots, Androids, and Animatrons, Second Edition
by John Iovine

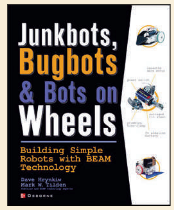


In *Robots, Androids, and Animatrons,* Second Edition, you get everything you need to create 12 exciting robotic projects using off-the-shelf products and workshop-built devices, including a complete parts list. Also ideal for anyone interested in electronic and motion control, this cult classic gives you the building blocks you need to go practically anywhere in robotics. **$19.95**

The Robot Builder's Bonanza
by Gordon McComb

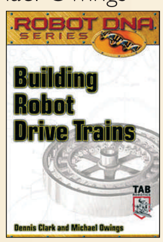
A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, LEGO Mindstorms Kits, and other commercial kits. **$24.95**

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now, you can use electronic parts from old Walkmans, spare remote controls, and even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot building revolution! **$24.99**

Building Robot Drive Trains
by Dennis Clark / Michael Owings

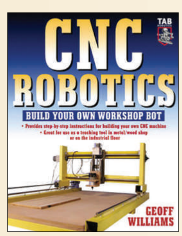


This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

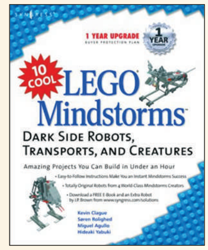
- The Basics of Robot Locomotion
- Motor Types: An Overview
- Using DC Motors
- Using RC Servo Motors
- Using Stepper Motors
- Motor Mounting
- Motor Control
- Electronics Interfacing
- Wheels and Treads
- Locomotion for Multipods
- Glossary of Terms, Tables, and Formulas

CNC Robotics
by Geoff Williams



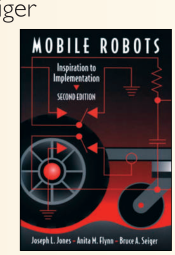
Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

10 Cool LEGO Mindstorms: Dark Side Robots, Transports, and Creatures
by Kevin Clague / Søren Rolighed / Miguel Agullo / Hideaki Yabuki



Okay, you bought the kit for yourself or one of your kids. You used the instructions in the box to build a robot or two. Now what? You may not be ready to design and build your own robots, but you don't want to build the same robot over again. This book is the perfect aide for building additional projects from the same kit, then improving and designing your own. Ten cool projects — one hour each — perfect! **$24.95**

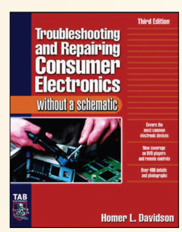
Mobile Robots: Inspiration to Implementation, Second Edition
by Joseph L. Jones / Anita M. Flynn / Bruce A. Seiger



Revised and updated, the second edition includes several new chapters with projects and applications. Robotics has made quantum leaps since the first publication of *Mobile Robots: Inspiration to Implementation.* With the publication of the second edition, the authors keep pace with the ever-growing and rapidly expanding field of robotics. The new edition reflects technological developments and includes programs and activities for robot enthusiasts. Using photographs, illustrations, and informative text, *Mobile Robots* guides the reader through the step-by-step process of constructing two different and inexpensive — yet fully functional — robots. **$34.00**

Electronics

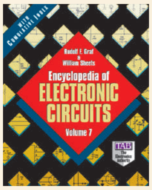
Troubleshooting & Repairing Consumer Electronics Without a Schematic
by Homer Davidson



In this book, Homer Davidson gives you hands-on, illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Call 1-800-783-4624 today! or order online at www.nutsvolts.com

Encyclopedia of Electronic Circuits, Volume Seven
by Rudy Graf

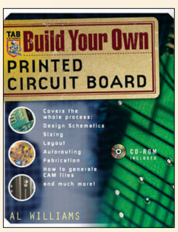


Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits*, Volume Seven, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants, such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Anti-Hacker Tool Kit, Second Edition
by Mike Shema / Brad Johnson

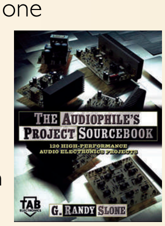
Get in-depth details on the most effective security tools and learn how to use them with this hands-on resource. A must have companion to the bestselling security book *Hacking Exposed*, this tool kit includes tips and configuration advice for getting the best results from the top hacking tools created and in use today. **$59.99**

Build Your Own Printed Circuit Board
by Al Williams



With *Build Your Own Printed Circuit Board*, you can eliminate or reduce your company's reliance on outsourcing to board houses and cut costs significantly. Perfect for advanced electronics hobbyists as well, this easy-to-follow guide is by far the most up-to-date source on making PCBs. Complete in itself, the handbook even gives you PCB CAD software — on CD — ready to run on either Windows or Linux. (Some PCB software costs from $10,000.00 to $15,000.00!) **$27.95**

The Audiophile's Project Sourcebook: 120 High-Performance Audio Electronics Projects
by G. Randy Slone



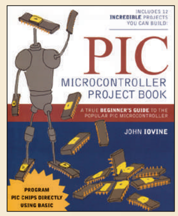
The Audiophile's Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

Microcontrollers

Programming & Customizing PICmicro Microcontrollers, Second Edition
by Myke Predko

This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICmicro's hardware architecture and software schemes complement the host of experiments and projects, making this a true "learn as you go" tutorial. **$49.95**

PIC Microcontroller Project Book
by John Iovine

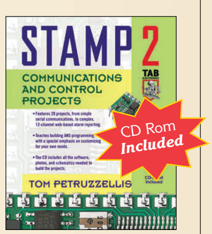


This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number loggers, distinct ring detectors and routers, home automation using X-10 communications, digital oscilloscopes, simulations of fuzzy logic and neural networks ... and many other applications. **$29.95**

Microprocessor Design Made Easy: Using MC68HC11, with CD ROM
by Raj Shah

This informative, hands-on training book explains Microprocessor Design using the Motorola MC68HC11. It explains, in detail, how the microprocessor works, including its architecture and its addressing modes. It also explains, in easy-to-understand language, the fundamentals of programming. Every chapter in the workbook ends with questions. This study guide uses EZ-Micro Tutor Board from AMS. **$55.00**

STAMP 2: Communications and Control Projects
by Thomas Petruzzellis



With the help of detailed schematics, informative photos, and an insightful CD-ROM, *STAMP 2: Communications and Control Projects* leads you step-by-step through 24 communications-specific projects. As a result, you'll gain a firm understanding of Stamp 2 and its programming methodologies — as well as the ability to customize it for your own needs and operating system. **$29.95**

The *Nuts & Volts* of BASIC Stamps, Volumes 1-4

$9.95 Volume 3

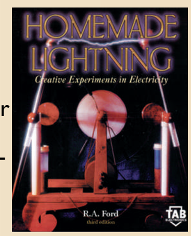
$14.95 Volume 4

$49.95 All 4 Volumes

In 1995, Scott Edwards began authoring a column on BASIC Stamp projects in *Nuts & Volts Magazine*. The column quickly became a favorite of *Nuts & Volts* readers and continues today with Jon Williams at the helm. *The Nuts & Volts of BASIC Stamps* is a four-volume collection of over 100 of these columns.

High Voltage

Homemade Lightning: Creative Experiments in Electricity
by R. A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and how experiments in high potential physics work! **$24.95**

Home Entertainment

Build Your Own Smart Home
by Anthony Velte

Wow! If you've got the time and inclination, there isn't anything that cannot be automated in your home. This one stop resource uses clear, step-by-step instructions and illustrations to show you how to plan and install smart home systems. Discover projects for automating entertainment systems, home security systems, utilities, and more. **$29.99**

If you don't see what you need here, check out our online store at **www.nutsvolts.com** for a complete listing of the titles available.

by Douglas Glenn

Magnetic Saturation and the 100 Amp DC Current Transformer

An Alternative to Using a Series Shunt

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

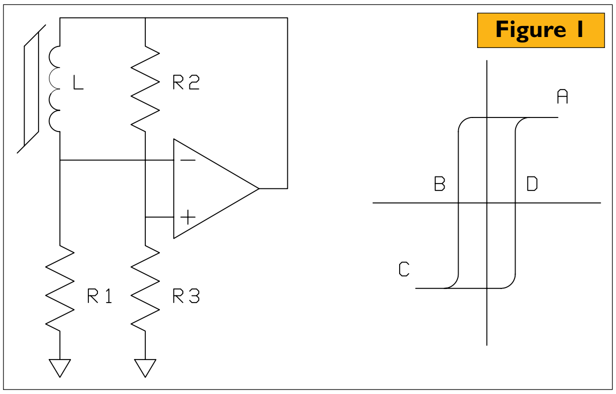
For most of us, measuring DC current means putting an ammeter or low resistance current shunt in the line. In either case, the result is that you intentionally add voltage drop to the line. The problem occurs when you want to check something that draws 20 or 30 amps and your DVM/VOM will handle only 2 or 10 amps. Using a current transformer can help solve this problem, since AC current is easier to handle than DC. A current transformer has an added benefit — the measuring circuit is isolated from the current being measured. There is also a way that you can do it with DC current. This project will provide you with an adapter that can be used with your voltmeter and will measure 100 amps DC.

Theory of Operation

In the simplified schematic (Figure 1), a free-running square-wave oscillator (multivibrator) is built around a voltage comparator and a toroidal inductor. In operation, positive feedback is provided by R2/R3 around the comparator to keep it oscillating. The timing is controlled by the inductor, which is wound on a "square-loop" core. "Square-loop" refers to the shape of the core's hysteresis curve, which has a sharp, well-defined transition when it becomes magnetically saturated. The current through the inductor is small before it saturates, but increases rapidly when the core saturates. The increasing coil current at saturation is sensed by R1 and switches the oscillator's state when the voltage comparator -IN exceeds the +IN.

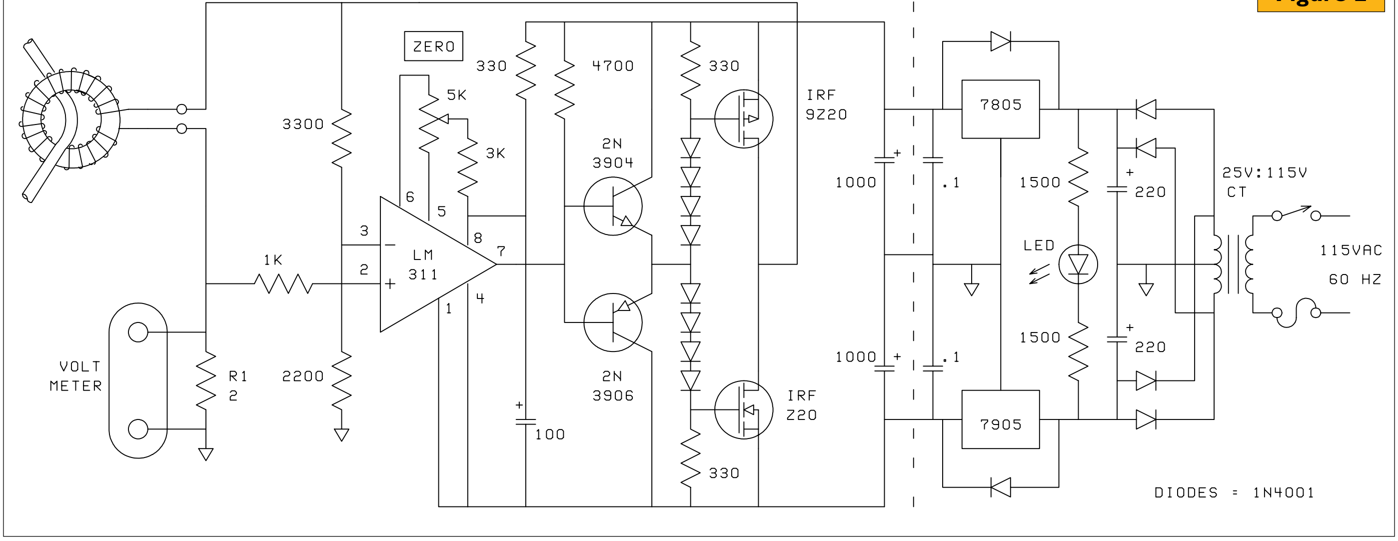
A typical hysteresis curve for the iron core of the oscillator's inductor is also shown in Figure 1. The vertical axis is flux density, usually measured in Gauss. The horizontal axis is magnetizing force, usually measured in Oersteds. Faraday's Law says that the magnetizing force is proportional to the number of turns, multiplied by the current in the turns. It is less common, but perfectly valid, to measure the magnetizing force in amp-turns. During a full cycle of oscillation, the operating point follows the curve from A, where it switches to negative, through B to C, where it switches positive, then back through D to A again. Notice that the area enclosed by the hysteresis loop on the left side is equal to and opposite of the area on the right side. If the oscillator keeps switching at points A and C, the total amp-turns over a full cycle is zero.

Figure 1



Suppose a second "sense" winding is added to the core and suppose also that DC current is flowing in the sense winding. Now, the core is biased in one direction by the added magnetizing current in the sense winding. The oscillator keeps switching at points A and C, so there must be a negative DC current in the main winding to keep the total at zero over a full cycle. This is exactly what happens. The oscillator timing shifts to produce a net DC current in the main

Figure 2



winding, which cancels the effect of the DC current in the sense winding.

Remember, it is the product of current multiplied by the number of turns that is balanced. A small current in a large number of turns can be used to cancel a large current in a small number of turns. All of the current in the main winding also flows through R1, so measuring the average DC voltage across R1 tells us the average DC current in the main winding. If we know the number of turns in both windings, we can find the DC current in the sense winding.

As an example, imagine that a wire carrying 100 amps DC is put through the center of the toroid. This forms a one-turn sense winding. The added magnetizing force is 100 amps through one turn, which equals 100 amp-turns. Suppose the main winding has 200 turns. To cancel 100 amp-turns in the sense winding, the DC current in the main winding must be (100 amp-turns)/(200 turns) = .5 amp DC (in addition to the AC oscillator current). If R1 is 2 Ω, .5 amp produces a 1.0-volt average. The scale factor is 100 amps per volt; i.e., there is 1.0 VDC across R1 with 100 amps DC in a one-turn sense winding. Figure 2 shows how this is accomplished in an actual operating circuit.

Design Details

The simple comparator detailed in the section above has been implemented using an LM311 integrated circuit, followed by an inverting buffer to supply the coil with current. Since the buffer inverts the signal, the +IN and -IN terminals of the comparator are swapped. The buffer consists of complimentary emitter-followers that drive complementary power MOSFETs in an inverting configuration. The emitter-followers present a high impedance to the comparator, but source enough current to rapidly charge the gate capacitance of the powerFETs. A string of four series diodes offsets the voltage to the gate of each powerFET so that the powerFETs can't turn on at the same time (which would put a short across the power supply).

The power supply provides ±5 V to operate the circuit. Three-terminal voltage regulators are used, which have built-in current and thermal protection, in case of a fault. When the coil core saturates, the current drawn suddenly increases, so large electrolytic capacitors are used on the ±5 V lines to stabilize the voltage during the current spikes. With large capacitors on the regulator outputs, a protection diode is connected across each regulator to keep reverse current out of the chip when the AC power is turned off.

A value of 1.0 volt was selected to represent 100 amperes, since it makes the meter reading easy to interpret. The feedback resistors, R2/R3, are selected so that the comparator trip voltage is ±2 V. This was arbitrarily picked, being twice the maximum 1.0-volt average DC voltage expected across R1. It is well within the common-mode range of the comparator, but much larger than the worst-case input offset voltage of the comparator. A network is included with a potentiometer which allows compensation of the comparator offset voltage; it is labeled “ZERO” on the schematic, since it is used to make the meter read zero, with no current being measured.

Since R1 is 2 Ω, the current at the trip voltage is 1

Figure 3

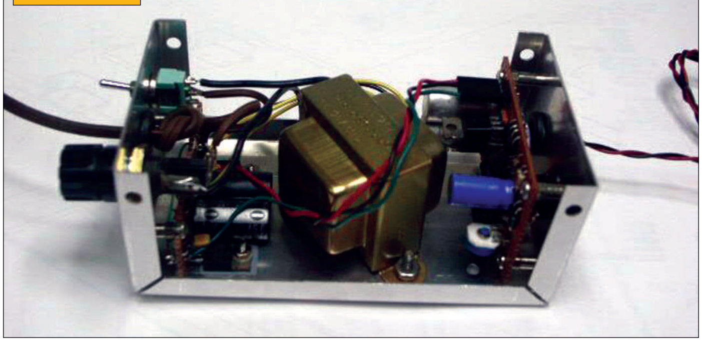



Figure 4

amp. This current is well within the rating of the powerFETs, won't put a strain on the power supply, and doesn't require heavy wire on the coil. At full scale, with 100 amps in a one-turn sense winding, there will be .5 amp in the main winding, so use a power transformer with at least a .5 amp rating.

PARTS LIST

Semiconductors

Transistors	2N3904, 2N3906
Integrated circuit	LM311N voltage comparator
Voltage regulators	LM7805 (+5 V), LM7905 (-5 V), TO-220 case
Power MOSFET	IRF9Z20 (P-channel), IRFZ20 (N-channel)
Diode	1N4001 (qty. 14)
LED	Red, T-1 (3 mm)

Passives

1/4W, 5% resistors	330 Ω (qty. 3), 1.5K (qty. 2), 2.2K, 3K, 3.3K
1 W, 5% resistor	2 Ω
Trimpot	5K
Ceramic capacitor	0.1 µF, 50 V (qty. 2)
Electrolytic capacitors	100 µF, 16 V (qty. 2), 220 µF, 25 V (qty. 2), 1,000 µF, 10 V

Inductors

Power transformer	120 V: 25.2 VCT, .45 A (RadioShack #273-1366)
Ferrite core	FT82-75 (Ocean State Electronics) or FT87-75 (Surplus Sales of Nebraska)

Miscellaneous

0.100” spacing perfboard, 5.25 x 3 x 2.125 metal enclosure (RadioShack 270-238), rubber grommets, fuse (5 x 20 mm, 1 amp) and fuse holder, toggle switch, banana plugs, 1/8-inch stereo phone plugs (and jack), 8-pin DIP socket for LM311N, TO-220 mounting insulator kit, 26 AWG magnet wire, 24 AWG bus wire, 24 AWG hook-up wire, PC board standoffs (1/2-inch long), line cord.

Building the Adapter

I built my adapter (Figure 3) by mounting the components on perfboard and soldering the connections on the back, using the component leads and/or bus wire. As seen in Figure 3, the adapter was built in a 5.25 x 3 x 2.125 inch aluminum box (RadioShack p/n 270-238). The power transformer (RadioShack p/n 273-1366) is mounted in the center of the box. This leaves the ends for mounting two perfboards on 1/2-inch spacers.

The oscillator section is on the right side of Figure 3. The “ZERO” adjust pot stands up on the board in the lower corner. There is a small hole drilled in the box to allow adjustment of the pot. Leads to the external meter exit to the right through a rubber grommet. An 1/8-inch stereo phone jack (RadioShack p/n 274-249) is mounted on the wall behind the oscillator. Its terminals are bent over to avoid touching anything on the board.

The rectifier/regulator section is at the left side. The voltage regulators are in TO-220 packages, attached to the box for heatsinking. The +5 V regulator has its metal tab grounded, so it's screwed directly to the box. The -5 V regulator's metal tab is not at ground, so insulating hardware is used between the regulator and the box. A T1 size LED is used as a power indicator. It is mounted on the perfboard, but its body sticks partially through an 1/8-inch hole in the box when the perfboard is screwed in place.

The heart of the design is the toroid coil. Recall that well-defined trip points on the hysteresis curve are crucial to good performance. This means a core with high permeability and good “squareness” is preferred, so the impedance change from unsaturated to saturated is large and well-defined. Tape-wound toroids and high-permeability ferrite toroids are obvious choices. Both types will work.

Figure 4 shows some different coil designs. The left coil has a 1-inch, tape-wound core (Magnetics p/n 51061-1A). The other three have 5,000 permeability ferrite cores. The large coil on the right has a 3.375-inch core. This is about the biggest ferrite core available; look for these at hamfests, where they are intended for use in high-power antenna baluns. Each of the two coils in the center has a .87-inch ferrite core. One uses MMG/Krystinel K82 material and the other uses Philips/Ferroxcube 3E2A material. I expect, but haven't verified, that almost any toroid of 5000-permeability ferrite material would work, as well. Results were just as good with a lower permeability material, such as 2,700; I experimented with Philips/Ferroxcube 3C8 in a .87-inch toroid. The coil shown at the bottom center of Figure 4 was made with a one-turn sense winding of 10 AWG connected to big lugs for those cases where you want to connect to a wire that already has big lugs,

but won't fit through the small hole in the toroid.

The main winding of each coil was terminated with an eighth-inch stereo phone plug. This allows different ones to be easily attached to the adapter. The coil winding is connected to the “tip” and “ring” terminals, since neither end of the coil is grounded. The grounded “sleeve” terminal is left unconnected.

Calibrating the Adapter

The number of turns on the coil and the value of R1 are directly linked. For example, if the resistance of R1 is 1% high, you compensate by increasing the number of turns on the coil by 1%. Once the adapter is built, wind the coil, but leave enough extra wire to be able to add several more turns, if needed.

For calibration, you need an accurate DC source in the range of 20 to 50 amp-turns. Wind a sense coil on the toroid, using hook-up wire that fits the amount of current you have to calibrate with. For example, 1 amp in 20 turns or 2 amps in 10 turns both give the same 20 amp-turns bias to the coil's core. With 20 amp-turns in the sense winding, the external voltmeter across R1 should read 200 mV. If the voltage is 1% too low, reduce the number of turns on the main winding by 1%. Add turns to the main winding if the external voltmeter reading is too high. Each turn added or removed affects the reading by about 0.5%, so you should be able to calibrate the readings within 0.5%.

Figure 5 shows a plot of data from one of the coils. It shows good linearity over the entire range. Once the turns are adjusted during calibration, many different cores can be used with the same adapter.

A note of caution: when you use sense windings with more than a few turns, the coupling of the sense winding to the main winding can cause ringing. This can make the oscillator have multiple transition bursts at one switching point and ruin the calibration. Whenever you use sense windings with many turns, add a second external coil in series with the sense winding to suppress the ringing. A good choice for the external coil is a winding with the same number of turns as the sense winding, but on a separate core. You can check for this waveform with a scope at the voltmeter terminals.

Using the Adapter

Using the adapter is straightforword; you put the wire carrying the DC current to be measured through the center hole of the toroid and read the value on an external voltmeter. There are, however, things you should be aware of.

There is a large AC component on the signal to the external voltmeter. Not all digital voltmeters do an equal job of ignoring this AC component. If you have problems getting a steady reading, try adding a low-pass filter between the adapter and the voltmeter; a 33K series resistor and a 0.1 µF capacitor across the DVM input should clear it up.

In Figure 4, the largest coil causes the oscillator to have a free-running frequency of close to 60 Hz. The beat note between the oscillator and the AC power line frequency made the DVM reading wander until I added the filter. With the other, smaller coils, the oscillator frequency is 400 to 500 Hz and wasn't a problem.

The voltage regulators can dissipate several watts when measuring larger currents, so expect the box to get warm. The box acts as a heatsink for the regulators.

Be aware that the oscillator in the adapter is producing a signal that is being coupled to the current being measured. If the gear you are testing is sensitive to a signal in the low audio range, you may find the adapter's signal getting into your external circuit.

Part Availability and Substitutions

Most of the parts used in this project are commonly available. The most notable exception is the ferrite cores for the sensor coils. Two advertisers found in *Nuts & Volts* have recently shown ferrite cores available through their websites. You might try p/n FT87-75 from Surplus Sales of Nebraska (**www.surplussales.com**) or p/n FT82-75 from Ocean State Electronics (**www.oselectronics.com**).

Power MOSFETs are becoming more available, but there still isn't much variety at many part suppliers, especially for P-Channel devices. Most power MOSFETs will handle the low voltage of this application, so look for parts with ID values from 5 to 20 amps, Rds from .1 to .5 Ω, and Cin less than 2,000 pF. In a pinch, use NTE2373 for the P-channel and a NTE66 for the N-channel MOSFETs.

Resistor R1 is 2 Ω, can dissipate a .5 watt average at full scale, and must handle a peak of 2 watts twice during each cycle of oscillation. A 1-watt device is a good choice here. Five 1/4-watt, 10 Ω resistors in parallel will also work fine. **NV**

ABOUT THE AUTHOR

Douglas Glenn is an Electronic Engineer and an Advanced Class Amateur Radio Operator, K3ZMG. This project resulted from the need to measure the current drain of an amateur radio transmitter.

Hand-held Messenger

Wave This Wand to Get Your Point Across

I am sure that everyone has the experience of being surprised by an unexpected message on occasion. It could be a declaration of love on a giant stadium screen, a greeting left behind by a plane, or a commercial sign beside the highway. Wouldn't it be nice to be able to deliver a personal message to impress your friends when they least expect it? Here is a simple gadget that enables you to wave your personal messages in glow-in-the-dark words, pictures, or both.

This Messenger project not only lets you surprise your friends with built-in light displays, but also provides you with an option of creating your own messages. The device is compact, portable, and electronically hi-tech! It is a toy that will appeal to people of all ages. It could be used for kids at home, fans at concerts, anyone in need of attention at night, outdoor celebrations, and even creative or educational purposes for students in school.

Description

The Messenger is a hand-held device which can display various LED messages when it is waved in the air. The working principle of the Messenger relies on the virtual retention of visual images of moving bright objects on the human retina. The common, flat panel LED displays we see in subway stations or on freeway signs show messages in a two-dimensional array of LEDs (columns and rows). To ease the controlling mechanism and reduce power consumption, columns of LEDs in such arrays are not on simultaneously. Instead, only one column of LEDs is triggered on at a time, while the control is cycled along the columns. Strictly speaking, the LEDs are dynamically flashing in sequence. However, the emitting intensity of the LEDs and the high refreshing rate of control render a practically stationary image to our human eyes.

Our Messenger adopts the same working principle, except that it provides only one single column of eight LEDs. The lights are controlled by a microprocessor to flash in a predetermined manner. Owing to the physical movement of the LEDs column in waving the Messenger, the changing pattern of the LEDs is displayed laterally. By matching the rate of changes of the LED's pattern, the intensity of the emitting light, and the swinging speed, static messages can be perceived and retained in our vision.

The microprocessor — which is dedicated to making various logical decisions — is the soul of the project. Not only does it reduce the controlling circuit into a compact size with a mere handful of electronic components, but it also enables the device to perform multiple tasks. In total, the Messenger offers eight operating modes:

Mode 1: Shows all LEDs on.
Mode 2: Shows all LEDs flashing.
Mode 3: Shows single LED running up and down the column.
Mode 4: Shows "2004."
Mode 5: Shows "I ♥ U."
Mode 6: Shows "HELP."
Mode 7: Shows personalized initials.
Mode 8: Sets programming mode for creating own pattern.

An example of a created pattern for my prototype — which spells, "Bless you," in Chinese — is shown in Figure 1.

Microcontrollers

I am not going to explain how to program a microcontroller, as it requires a full article on its own. I have, however, included a logical flowchart (Figure 5) for the Messenger controlling processor as a reference for those who are ambitious enough and would like to program their own processing units. (A HEX image of the PIC code is available for download from the *Nuts & Volts* website at **www.nutsvolts.com**) There are too many microprocessors available on the market for me to exhaust them all. Therefore, I will include some simple, generic routines in assembly language to illustrate the basics and leave the fine-tuning to my readers.

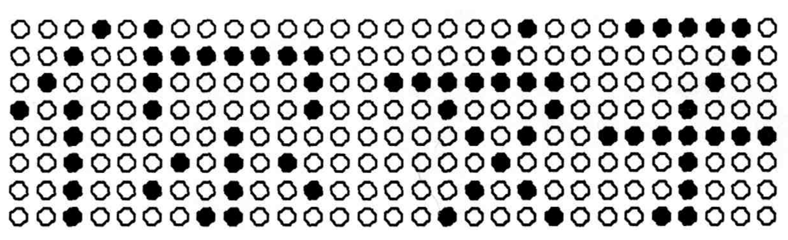
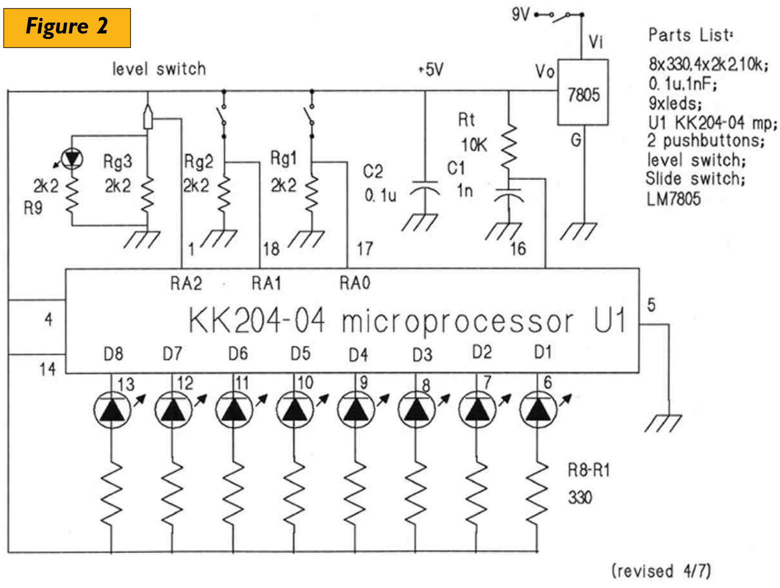


Figure 1. Example of a programmed message.

Figure 2



Bear in mind that logic 1 in outport bit represents the ON-state and logic 0 represents the 0FF-state for the connected LED. In order to enable Mode 1, all we have to do is output all ones to the eight-bit output port, which could easily be done in the following two lines:

```
movlw   b'11111111'   ;move all ones to working register- LEDs on
movwf   port          ;export working register value to output port
```

By understanding the principle illustrated in the previous routine, we could easily enact Mode 2 simply by repeating it to make the LEDs flash:

```
movlw   b'11111111'   ;Turn all LEDs on
movwf   port          ; Drive the port
movlw   b'00000000'   ;Turn all LEDs off
movwf   port          ; Drive the port
```

It follows that, by repeating the steps and changing data for the output port, different display patterns could be achieved.

About the Circuit

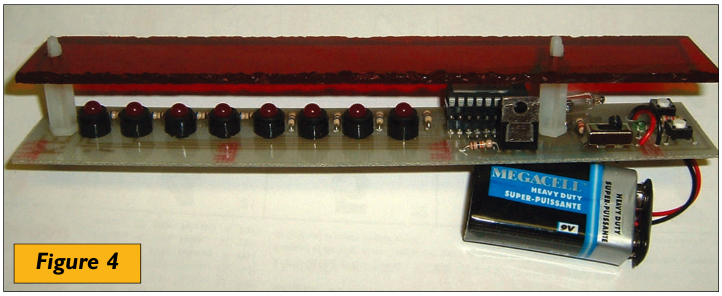
The schematic is shown in Figure 2. The microprocessor, U1, provides eight output bits for LED display and three input bits for operating mode selection. Two push-buttons, S1 and S2, serve as inputs to U1. They are used for the selection mode, as well as for the program mode. In the selection mode, S1 sequentially toggles the eight function modes of the Messenger via pin 17, whereas S2, at pin 18, is used to confirm the choice of the selected mode. The reset button, S0, is essentially an on/off switch and provides the user with the ablility to reset the Messenger back to the monitor modes selection. Once a display mode is confirmed, control is then passed over to the level switch, S3 (pin 1). The level detector I used is a simple tube-mercury switch, which costs 50 cents and can even be homemade. Movement of the Messenger will cause S3 to toggle and, thus, initiate the Messager to start displaying the message. The rate of the flashing LED sequence is optimized for the best visual effect.

In the programming mode, S1 shifts the relative LED positions along the column, while S2 toggles the selected LED on/off. When it reaches the end of the LED positions in the column, it stores the programmed byte in memory and then proceeds to the beginning position of the next display byte. U1 has a memory storage capacity of 64 bytes of data, which simply translates to 64 different column display states. Simultaneously pressing both buttons will terminate the programming mode and reset the Messenger back to a selection mode.

IC1 converts a 9 V battery into a steady 5 V power supply to the circuit. The series 10K resistor and 0.001 µF capacitor form an oscillating clock for U1. The 330Ω resistors limit current through the LEDs. Lower resistances could be used for brighter light; however, values lower than 100Ω are not recommended because the LEDs

Figure 3

Figure 4



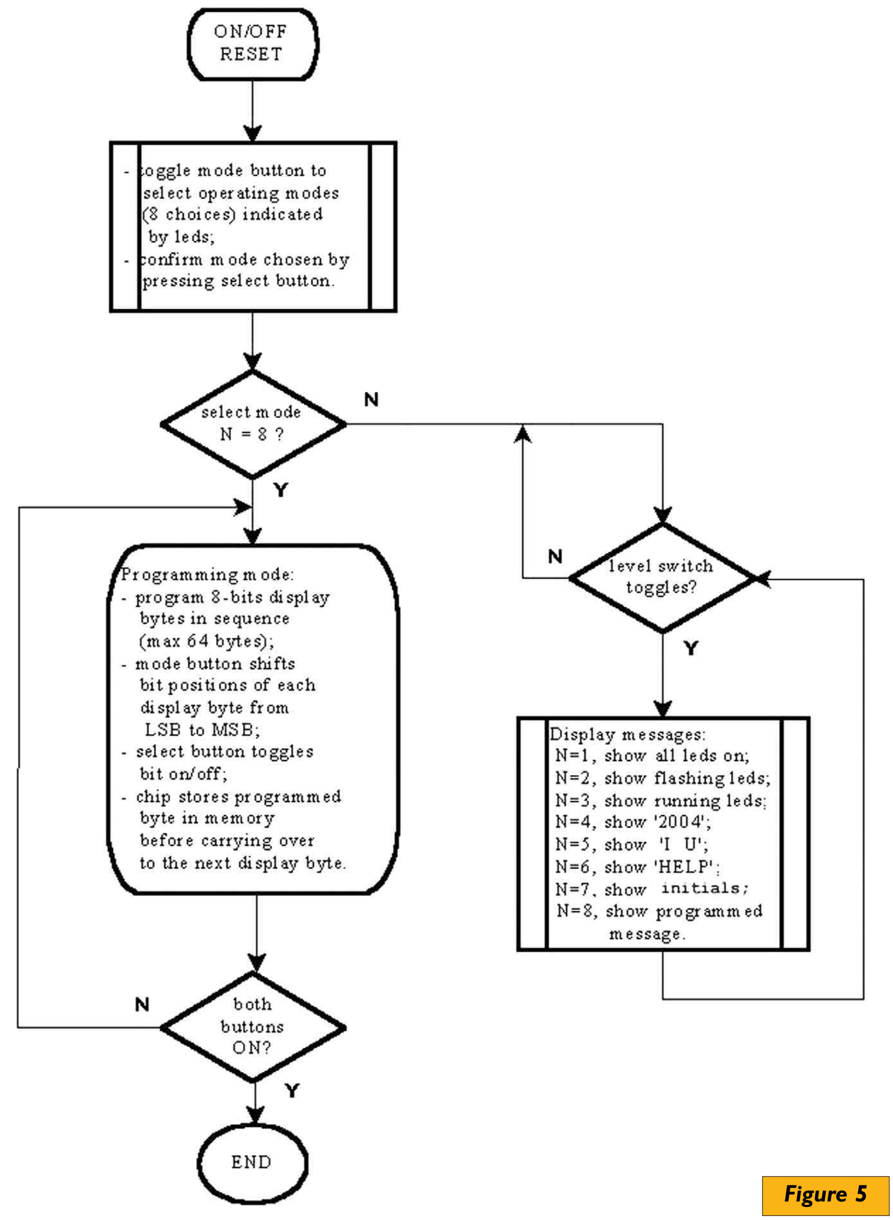


Figure 5

could be damaged or U1 might operate erratically. As the microprocessor sleeps when it stands idle, the entire circuit consumes little power. A battery could, therefore, go for a long time.

Construction

Due to the high cost of U1, an IC socket is highly recommended to house the chip to avoid damage to the IC during soldering. Physical separations between LEDs have to be set in accordance with the waving speed to output realistic message proportions. The slower the movement, the denser the LEDs should be packed. The level switch should be adjusted after the final assembly of the project. The switch needs to be oriented in such a way that the display pattern starts at the nine o'clock position and goes clockwise. An etched PCB (also available from the *Nuts & Volts* website) is not absolutely necessary, but it will save you the tedious routine of wiring. An opaque casing for the circuit with LED sockets will be a great plus for the Messenger, as it helps to broadcast LED intensities in a forward direction. As with most billboard

Parts List

Resistors

R1-R8	330Ω
R9, Rg1-Rg3	2.2K
Rt	10K
Capacitors	
C1	1 nF
C2	0.1 µF
LEDs	
L1-L8	3 mm LED
L9	1.5 mm LED (optional)
Switches	
S0	On/Off slide switch
S1, S2	N.O. pushbutton
S3	Level switch
Semiconductors	
U1	KK204-04 microprocessor (available pre-programmed from the author)
IC1	LM7805 voltage regulator
Miscellaneous	
PCB, 9 V battery snap, 18-pin IC socket	

Author Bio

Michael Chan, CEng MIEE, graduated in 1980 with a Masters Degree in Electrical Engineering, and worked as an electrical engineer for four years. Currently, he teaches electronics, computer technology, and robotics at Albert Campbell C. I. in Scarborough, Ontario. Descriptions of his recent work can be found at **www.geocities.com/keensd**

signs, a red plastic filter on top of that will greatly enhance the illumination. L9 indicates the readiness of the Messenger to display a message. As it is used to help the operator to coordinate the movement of the Messenger, make sure it is bent toward the direction of the soldered side. For advanced hobbyists, L9 may be redundant and could be taken out altogether.

Conclusion

The project presented here is very easy and inexpensive to build. The Messenger can be lots of fun for people of all ages. You could use it for catching attention, advertising promotions, artistic expression, or games. With a few dollars and an hour of assembly time, you can make yourself a personal messenger for fun and practical applications! **NV**

by J. Ronald Eyton

Optoelectric Gardening

Try Your Electronic Thumb at "Growing" an Electro Luminescent, Fluorescent, LED Flower

Optoelectronic components are intriguing devices, but are sometimes difficult to incorporate into projects.

Two such components — a miniature fluorescent tube and an electro luminescent (EL) lamp panel (see Figure 1) — were used to fabricate an optoelectronic flower in order to understand how these parts worked and to see how they looked in a demonstration project. The flower was made using a 165 mm x 6 mm green fluorescent tube as the stem and six petals cut from an EL lamp panel to make up the flower. A jumbo red LED was used to illuminate the center of the flower.

Battery-driven inverters were used to power the fluorescent tube and EL lamp petals. These were placed in a separate project box and wired through a DPDT toggle switch.

Three AA cells (4.5 volts) were used to power the EL lamp inverter. Normal input is recommended to be 3 volts to obtain a 300 hour lamp half life; however, up to 6 volts can be used as input if a brighter display (with a shortened half life) is desired. The inverter that drives the green fluorescent tube requires a 12 volt input, but a 9 volt battery connected to the inverter will illuminate the tube with reduced light output. This works well because the green fluorescent tube is too bright at 12 volts input and overwhelms the EL flower petals, even when 4.5 volts are used as the input to the EL lamp inverter. A red LED was used to light up the center of the flower and uses the 4.5 volt power supply and a 470 Ω series resistor, all wired through the DPDT toggle switch. Figure 2 shows the completed project.

Construction details are shown in Figure 3; see Figures 4 and 5 for front and back views of the completed flower. An inexpensive, plastic salt shaker top — the kind sold for picnic use — was used as the base for the flower petals and LED. A copper-plated perfboard was cut (nibbled) into a rough 1-1/2 inch diameter circle that just fits into the salt shaker top. The six petals were fastened to the perfboard with GOOP and then wired in parallel. The LED and series resistor were soldered to the perfboard and then the two green wires were connected to the 4.5 volt battery power supply. The perfboard — with petals and LED — was inserted into the salt shaker top and GOOPed into place. Finally, the salt shaker top with perfboard was (You guessed it!) GOOPed to the top of the fluorescent tube. The fluorescent tube was pushed

Figure 1. Electronic components used to construct the electro luminescent, fluorescent, LED flower.

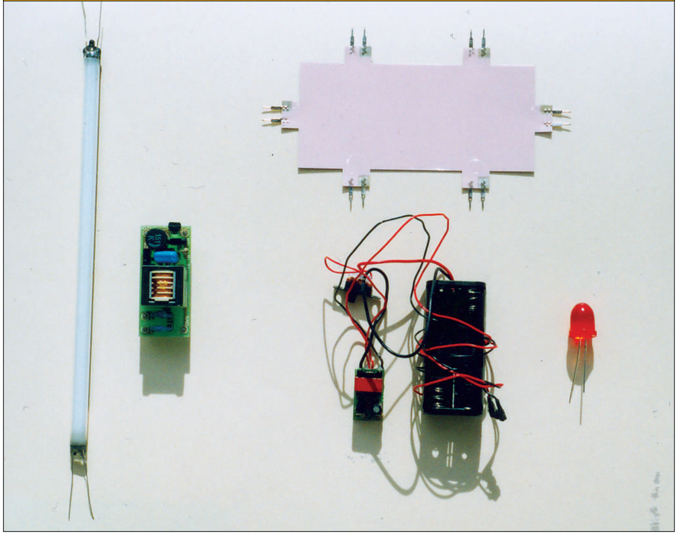


Figure 2. Completed project, shown with attached power supply.

Parts List

From www.allectronics.com
- Green fluorescent lamp 6 mm x 165 mm #BF-61656
- 12 volt DC inverter #BXA-12529
- Electro luminescent experimenters kit #EL-340
- Alternative electro luminescent experimenters kits:
- Jumbo EL kit #EL-2504
- Electro luminescent chaser kit #EL-2502

From RadioShack
- 10 mm red LED #276-086
- 6 x 4 x 2 inch project box #276-086
- DPDT toggle switch #275-663
- One half of dual mini board #276-148

Miscellaneous
- Rubber standoff
- 470 Ω resistor
- Battery holders
- Clear plastic salt shaker top
- Flower pot
- Artificial silk leaves
- Amazing GOOP all-purpose adhesive and sealant

through the drilled out hole in a rubber standoff (or project box foot) with the wiring done through holes

Figure 3. Construction Diagram.

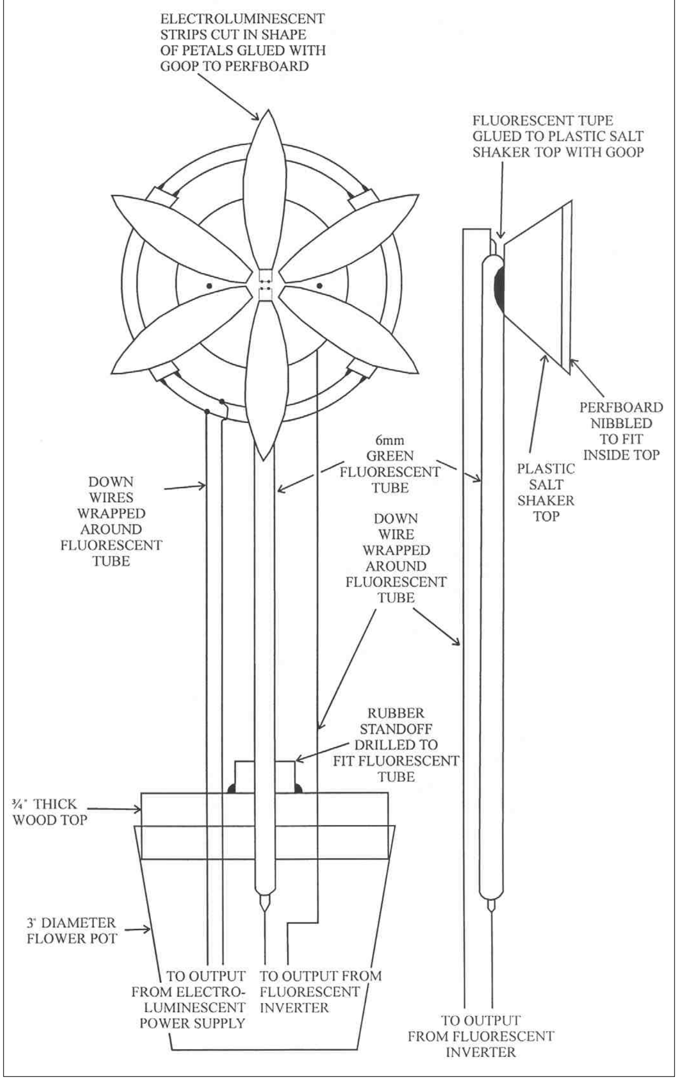


Figure 4. Front view of the flower, showing construction details.

Figure 5. This back side image of the flower provides another view of the wiring.

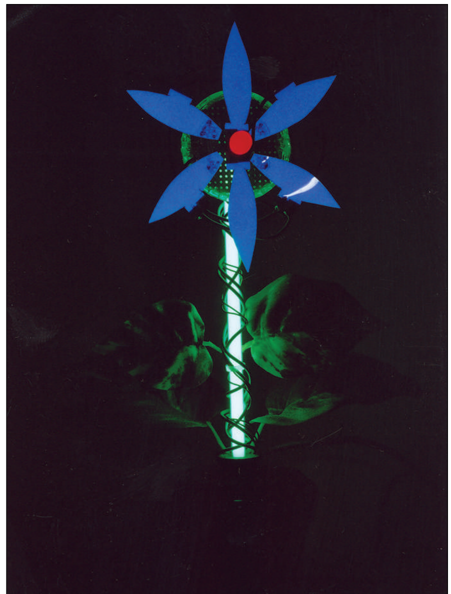


Figure 6. This long-exposure photo shows the flower and stem illuminated.

drilled in the circular, wooden flower pot top and through a hole drilled in the back of the flower pot.

All wires coming from the flower were braided around the fluorescent tube before being pushed though the holes in the wood pot top. An additional hole was drilled in the wood top to accommodate the stem of the artificial leaves. The entire assembly was (sigh!) then GOOPed to the flower pot.

The electronic flower is attention-getting whether it is illuminated (see Figure 6) or not. The half life of 300 hours means that, after 300 hours, the EL petals will be half as bright as when new.

Figure 7. A completed, illuminated optoelectronic flower.

To conserve the life of the EL lamp, it might be better to use a momentary pushbutton switch instead of the DPDT toggle switch used in the prototype. There are slightly different versions of the EL lamp kit available (see Parts List), including a jumbo 4 x 6 inch EL lamp panel for making a large flower and an EL lamp chaser kit for making a flower that has sequentially lit petals. The EL lamp kits all come with adhesive-backed color overlays, so that many different colored flowers are possible. All of the above provide lots of options for "growing" your own unique optoelectronic garden. **NV**

Alonzo Trueland

R/C Lap Timer/Counter

Step One in Your Home Grand Prix Track

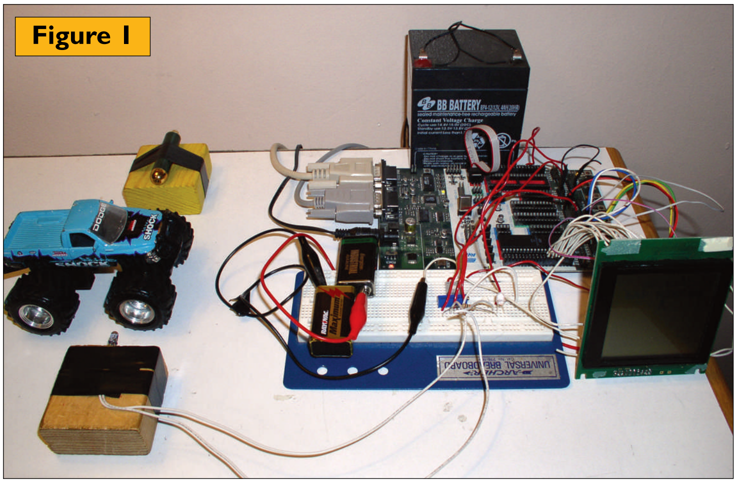
Radio controlled (R/C) hobbies have made steady increases in popularity during recent years. The increased media coverage and advancements in radio control technology are propelling the hobby to new levels. People of all ages are discovering the many rewards that come with maintaining and piloting these high-tech machines.

The heightened demand for RC gear allows manufacturers to offer quality products at reasonable prices. RC car racing is one area that has grown exponentially because of the reasonably priced equipment available. It has reached a level of competitiveness that rivals full-scale racing. Factory sponsored races and drivers have turned this hobby into a sport.

Practice is a big part of a competitive racer's schedule. To get the most out of practice sessions, performance monitoring is important. Recording the time it takes to complete laps around the track is a valuable tuning tool when setting an RC car up for competition. One option is to use a notepad and stopwatch to record lap times.

The stopwatch method requires a helper and also introduces human error, which could corrupt race data. A better solution is an electronic lap timer/counter device that would automatically measure, record, and display the time it took to complete each lap, along with statistics about the test session. I am always looking for new project ideas that enhance other hobby interests; this challenge does just that.

Figure 1



Description

The lap timer was designed to be used as a tuning tool for competitive racers. The unit uses a break-beam detection method for lap timing/counting. A laser module is located near a convenient part of the race track, with its beam cutting across the designated race path. A phototransistor connected to the timer/counter receives the laser beam at the other side of the race course, completing the detection circuit. Each pass of the RC vehicle through the laser will trigger the timer/counter to record and display the lap number and time on a graphic LCD display. After the session is over, lap times and statistics can be reviewed.

Lap information and statistics are also printed out from the serial port to an optional computer interface for saving to a file. The lap timer was designed as a training incentive rather than a multi-car race tracker. It is difficult to support multiple cars with the break-beam method, but possibilities do exist with some fancy detection methods and software magic. I have found solo running to be beneficial when a group of racers gets together to put their skills to the test for bragging rights. The potential argument over one person's "bad driving" disrupting the progress of others is eliminated.

Hardware

The Circuit Board

For this project, I chose the STK500 development board from Atmel as my final project circuit. The typical development process would have me design and test the project using the STK500 development board with the intention of building the circuit using a different board. I had an extra development board just collecting dust and begging to see some action. It is economical to use the STK500 because it is available for the same price as a pre-built controller board with the same features. Using the STK500 allows me to easily make changes and enhancements that would otherwise be tedious with a purpose built board.

The STK500 is fitted with the included ATmega163 controller, running at 4 MHz. Figure 1 shows the lap timer/counter on the bench during the development phase — this is the ugly part. Two female prototype headers are available on the STK500 that interface to the installed controller,

called expansion header-0 and -1. Figure 2 shows the connection of the display to header-0, along with pin descriptions. The sensor and support components interface to the controller using the board's male pin headers. The project is powered by a 12 V rechargeable battery that I borrowed from my house alarm — I hope the power doesn't go out!

I won't dwell on the use of the STK500 development board. The board comes with a printed manual and a CD ROM disk to help the user. The builder should have a good working knowledge of the STK500 before attempting any development. The board uses surface mount components that are difficult to replace if destroyed by incorrect connections. You can order your very own STK500 board from DigiKey at **www.digikey.com**

The Display

The lap timer uses a 128 x 128 pixel format, graphic LCD display. Graphic displays are my favorite type of controller peripheral because they provide an electronic canvas that allows the builder to get in touch with his/her creative side. I found it rewarding to see my bitmap designs come to life electronically during the project development.

I purchased the display (RG128128a) from Okaya Electric at **www.okaya.com** This display has the popular Toshiba T6963C as its controller. It was important for the display to have the T6963C because the software used to develop the project supports this type of graphic chip very well; more information on the software will be discussed later. Most graphic displays need special attention when connecting the contrast voltage due to the confusing negative voltage polarity that is required. Read the spec sheet carefully before connecting. To satisfy this requirement, I used two 9 V batteries in series. I then connected the batterys' positive lead to the STK500's 5 V signal ground lead. This provided a total voltage potential of 23 V between the +5 V of the STK500 and the negative lead of the 18 V battery pack. A 20K pot — inserted between this potentiometer with the wiper arm connected to pin four (contrast adjustment) of the display — is used to excite the liquid crystal. The specs for this display state that the maximum voltage between V_{dd} and V_{ee} is 22 V (the 20K pot connection). Using the two 9 V batteries exceeds this spec by one volt, so be careful not to adjust the 20K contrast pot to its maximum or possible display damage may happen. Some displays have built-in contrast voltage generators and pots that would reduce potential connection error, but they are more expensive. The user should be confident with the proper connection before using the display to prevent a costly mistake. Okaya has a .pdf file that describes the connection; a phone call to a

Special Notes

Using the STK500 as the project's final circuit board simplifies building and allows for changes to be made easily. If you get tired of the timer/counter's look, you can change the graphics in software for a different visual interface. It is important to fully understand the correct connection of the chosen graphic display and the usage of the STK500 development board. The STK500 does not have a prototyping area, so a small perf-board could be used for support components, like the 20K trimmer pots. A soldering iron and basic hand tools should make assembly quick. A multi-meter is always helpful in project building, especially for adjusting the comparator's input. A drill and a small block will be needed if the builder chooses to use the same sensor mounting method as described in the article. A toy block with a 6 mm hole in it provided the needed sensor support and protection. A speeding RC car can easily damage your timer/counter, so a rugged housing is a must, unless you are a perfect driver who never makes mistakes — I haven't found one yet!

It is important to always practice laser safety when using any device capable of emitting laser radiation — no matter how small. Never stare directly at the beam. View the beam's reflection at a safe distance when aligning it. Eye damage can occur even at the beam relatively low power levels of basic pointing devices when they are not used correctly.

Figure 2

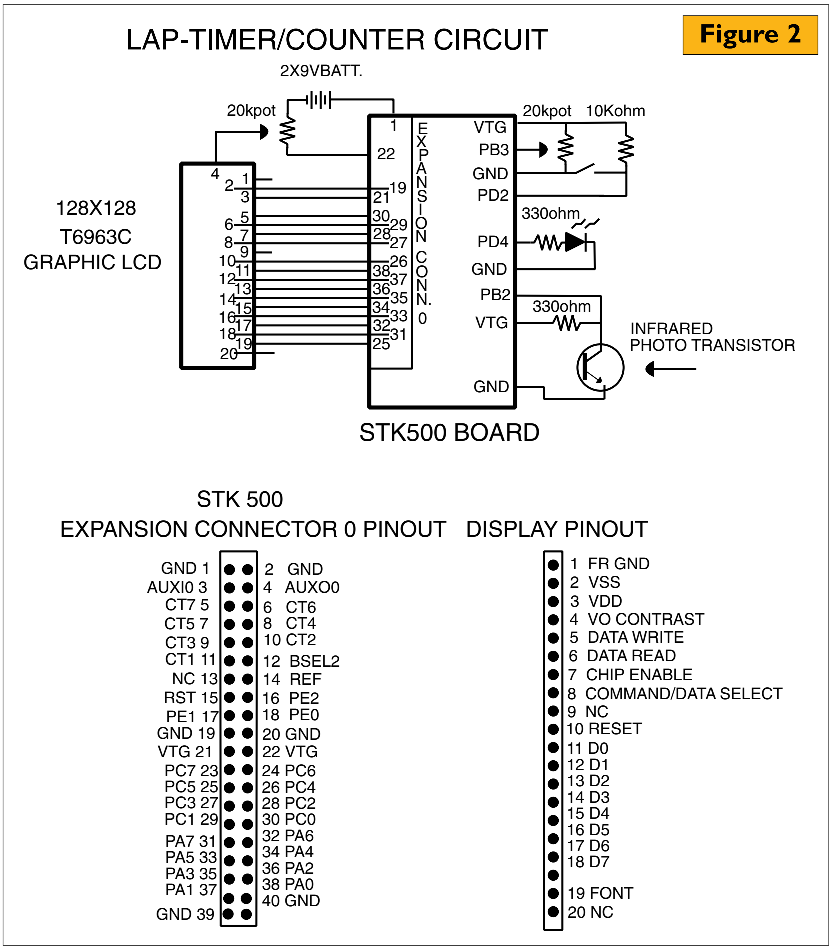


Figure 3

sales person will also get you connected the right way. Another good source for displays is AZ Displays at **www.azdisplays.com** AZ Displays has displays with the described onboard contrast voltage generators.

Laser Module and Sensor

The laser beam generator used to detect the car passing by is a simple pointing device. Laser pointers are not the best choice for this application because they are not designed for continuous duty. I destroyed a few pointers during the testing, but they are cheap and easily replaced. A better solution would be to purchase a laser module designed for rugged use. Commercial lasers can be a little pricey, but they are worth the money if you are serious about performance. A visible red laser is the best choice for this project and makes alignment easy. An infrared laser would work, but it is difficult to align the invisible beam. The phototransistor used to detect the laser has a bandwidth between 620-980 nm. A typical red laser has a wavelength of about 650 nm, just within the limit of the transistor. DigiKey has suitable laser modules for this application.

As mentioned above, the laser detector is a simple infrared phototransistor. The transistor is designed to turn on when light in the 620-980 nm bandwidth strikes its surface. The laser is just within the detector's wide range, but this is not a problem because the powerful laser easily saturates the phototransistor, creating a nice switching effect.

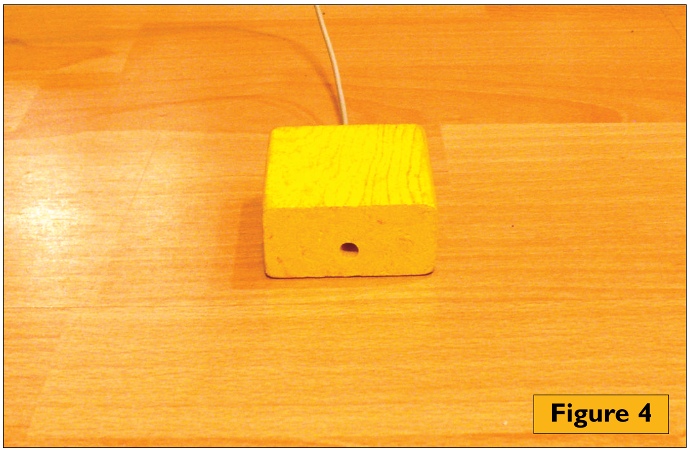


Figure 4

Interfacing the sensor to the MEGA163 is made easy by using the controller's built-in comparator input. The ON/OFF state of the analog sensor does not yield a perfect TTL output, which would be needed if it were connected to a port pin. The sensor output floats slightly above zero when turned ON and, inversely, is not a perfect +5 when turned OFF. The comparator will trigger an event when its sensor input, AIN0, goes above the AIN1 input that is set with a 20K pot. A voltmeter should be used to adjust AIN1 to be about one volt above AIN0 while the beam is focused on the photosensor. This is a handy feature for analog connections.

Since the transistor is designed for the infrared region, ambient light has little effect on it, but, to reduce ambient light triggering even further, the sensor is housed in a wooden block with a hole drilled in it to support beam entry. This method has proven to work very well and could also be used for many other detection circuits.

The Software

The development software (BASCOM-AVR) used to program the STK500 is an easy-to-use BASIC language compiler from MSC-Electronics; it has loads of features that make programming a breeze. You can find out more information about the many products that MCS-Electronics has to offer at **www.mcselec.com**

The program for this project is somewhat lengthy, making it impossible to print the entire listing. A full listing and explanation is not needed for a program written in Basic because of its readability. Most enthusiasts are able to gain a good working knowledge of how a particular Basic program works, even if they are not a programmers. The English speaking mnemonics lends itself to a short learning curve that can be easily mastered with a little effort. The BASCOM-AVR manual and help files are well written and easy to use. A complete listing with all associated files can be downloaded from the *Nuts & Volts* website (**www.nutsvolts.com**). However, there are some noteworthy features that helped make this project a relatively painless venture and deserve recognition.

One of the coolest features of BASCOM-AVR that I was eager to exploit was the graphic LCD support. Just a week before MCS-Electronics released its software version that supported graphic LCDs, I struggled with my own code to support these displays. After many lines of code and even more cups of coffee, I had a library ready to use. I was now ready for a graphic project, so I decided to download the latest version of BASCOM for the new project. As I read the revision update file, there it was: "GRAPHIC-LCD SUPPORT" — AHHHHH!!! All of my hard work was quickly reduced to nothing, but I am okay now and I am happy to be using the new features.

Listing 1 shows the small amount of BASIC code that is actually needed to get your display "talking." The first

step is to use the "CONFIG GRAPHLCD" that tells the compiler what pins are connected to the display and what their functions are. For now, the T6963C and SED type displays are the only ones supported by BASCOM. A breakdown of the config statement is as follows:

- TYPE = Pixel x pixel count
- DATAPORT = Data D0-D7 connections
- CONTROLPORT = Designates what port and which pins are for control signal connections
- RESET = What pin is for the display reset function
- FS = Font selection connection
- MODE = Number of columns for text mode

After the display has been configured, we are ready to talk to the world. Two main methods of displaying information are the LOCATE/LCD and SHOWPIC statements. The LCD and LOCATE statements are used for displaying text that is generated by the onboard character generator, while the SHOWPIC statement is used for graphics.

Displaying Text

Each character fits in an 8 x 8 pixel block that cannot be changed. The 128 x 128 pixel display that is used for this project will support 16 rows of 16 characters, for a total of 136 characters. It is best to clear the display's memory with the CLS statement before outputting anything to the screen. I did not want a cursor for this project, so I turned it off using the CURSOROFF statement. The location of the text is controlled using the LOCATE Y, X statement where Y is the row position and X is the column position; (locate 1,1) will place the text cursor in the upper left corner. To write some text at the current cursor position, the LCD statement is used. LCD "HELLO" is used when a string is to be printed and, if a variable needs to be displayed, LCD A would print the value stored in A. This is almost too easy!

Showing Some Pictures

Before you can show some art, you must first create it. All of the images for this project were done using Windows Paint. The easiest method I found was to set the unit of measure to "pels," set the zoom to a large size, and turn the grid on. The height and width options are then set to the desired graphic size. A width setting of 128 by a height setting of 128 will fill the entire display used for this project. You then start creating an image by using the drawing tools and saving the file. Once a bitmap has been created, the BASCOM "GRAPH CONVERTER" tool is used to create a file that is inserted into the program for displaying the bitmap.

The converted file will have a .bgf extension and must reside in the same directory as your Basic program. Listing 1 shows how the "$bgf" directive is used to place the file into the program code. Once the file is in the program and a line label is assigned, the "SHOWPIC X, Y, LABEL" is used to reveal your work of art. X is the horizontal point and Y is the vertical point used to locate the upper left corner of the

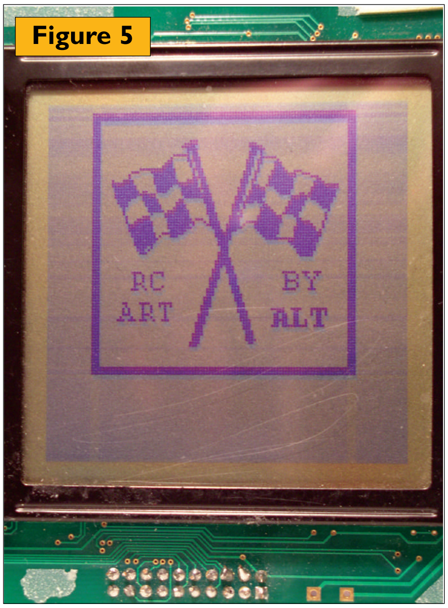


Figure 5

Figure 6

Figure 7

graphic to be displayed. LABEL in the SHOWPIC statement holds the line label where the graphic file is stored.

I would not have attempted this graphics-intensive project with any other compiler. I have not found another development platform in BASCOM's price range that has such a rich set of graphic tools and other features. Using BASCOM-AVR put the fun back in programming.

Using the Timer/Counter

Ease of use was a design goal for the timer/counter that was achieved with the use of a single pushbutton for function control. Figure 3 shows the unit ready for action with its simple layout. The timer/counter found its way into a small plastic toolbox. The rugged design worked well to keep the electronics safe from my not so careful Research and Development Team (Figure 3).

To use the unit, you simply place the timer/counter in a safe area near the racetrack, but not in the path of the speeding cars. The sensor cable length used for this project was two feet. The timer/counter could be located further from the action with a longer sensor cable, but I have not experimented with this. If a longer distance were needed, I would recommend a CAT5 type cable with its eight wires tied together to form two conductors of four wires each. The combined conductors will reduce wire resistance while the CAT5 cable will lower interference problems.

The laser module is placed on the opposite side of the track with its beam crossing it and focused on the phototransistor. I typically used a distance of five feet between the laser and sensor, but longer distances are possible with higher quality lasers. The mounting method of the sensor in the wooden block (Figure 4) makes the alignment process easy by providing a positive target.

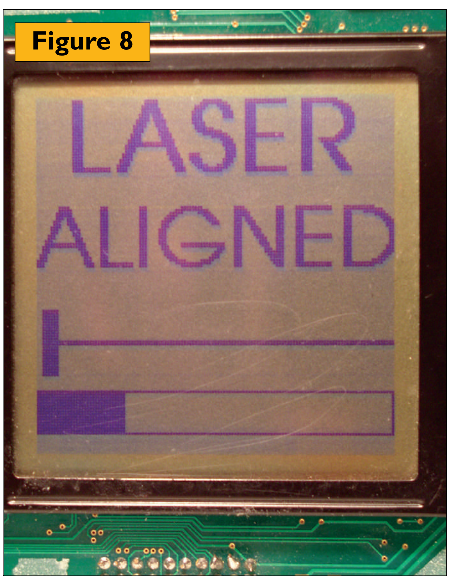


Figure 8

Figure 9

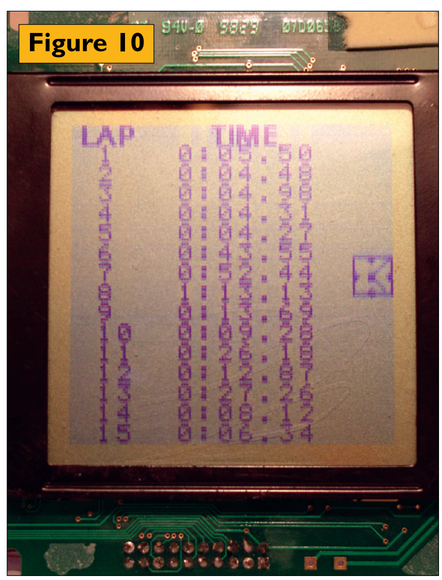
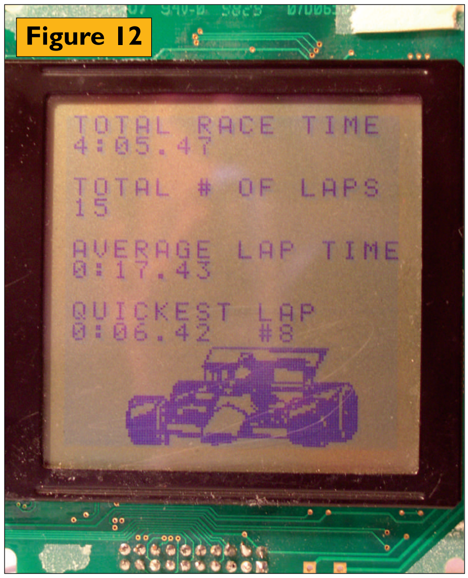


Figure 10

Figure 11

Figure 12



Aiming the laser down the hole in the block is all that is needed to insure a good alignment.

After the timer/counter is powered up by a connection to my trusty 12 V alarm system battery, the LCD will display a flag bitmap (Figure 5). Programmers sometimes refer to a personal touch in a project as an "Easter egg"; the flags are my Easter egg addition. After five seconds, the unit will require you to enter a lap number that is to be marked (Figure 6). The lap marker provides a visual indicator (the red LED on the unit) that a selected number of laps have been completed. By holding the timer/counter button down, the lap selection will increment once a second until the button is released. If no marker is needed, selecting zero will prevent the LED from lighting; otherwise, the LED will light after the completion of the selected number of laps. I chose an LED rather than an audio indicator so you can continue to race without having to listen to an annoying buzzer.

If the laser is not already aligned, the text in Figure 7 will be displayed. The unit is now waiting for the laser to be aligned with the sensor. After alignment, Figure 8's display will be seen during laser confirmation. The progress bar at the bottom will move as it checks for a stable beam. If the beam is broken during this check, the unit will wait until a steady beam is detected.

Once a steady beam is present, the text shown in Figure 9 will pop up,

Parts and Tools

Parts:

- STK500 development board with mega163 controller
- 128 X 128 graphic display with T6963c controller
- 4 MHz crystal
- 2 20K pots and resistors (see schematic)
- 2 9 V batteries (for display)
- LED (lap indicator)
- Push button switch
- 12 V rechargeable battery (project power)
- Infrared phototransistor (must be below laser wavelength)
- Laser module (650 nm wavelength — or longer)
- Wooden block (for sensor mount)
- Suitable project enclosure (a small plastic tool box works great)
- Hook-up wire
- DB9 computer cable (for downloading)
- Small piece of CAT5 cable or similar (sensor connection)

Tools:

- BASCOM-AVR software
- Voltmeter
- Small cutters, pliers, strippers, screwdrivers, etc.
- Drill (for sensor hole in wooden block)
- Soldering iron
- PC with terminal software (optional info saving)

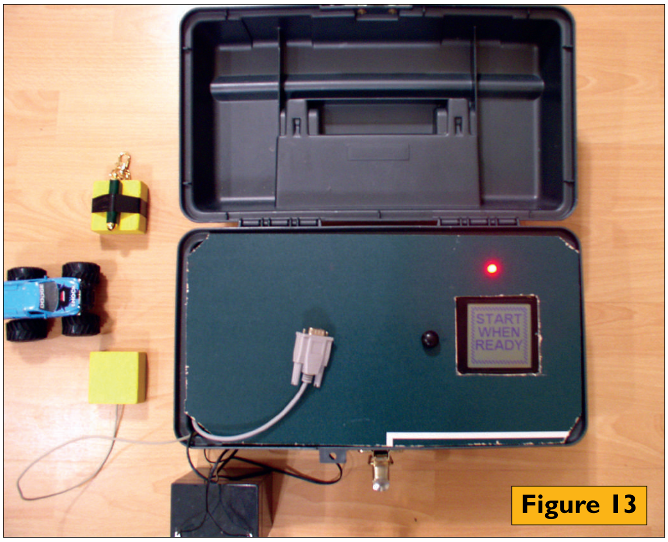


Figure 13

indicating the race can begin. When the RC car passes through the laser beam, the unit will display the completed laps and the time needed to complete them (Figure 10). After 15 laps are completed, the LCD will clear itself and begin to display the next 15 laps. If the laser beam is interrupted for more then three seconds, timing/counting stops and the message seen in Figure 11 will be displayed, indicating an error, but completed laps can still be reviewed. During the race recording, a small clock icon will scroll down the display, indicating proper operation. Lap counting will continue until the unit's function button is pushed, which stops the timing process and enters the review process. Additional presses of the button will display lap information that was recorded during the test session, 15 laps at a time.

Lap review looks exactly like Figure 10, except that the last lap in the review will have the word "END" printed next to it. The timer/counter can store up to 124 lap times in its EEPROM, but it will continue to display lap information on the display after the memory is full. One additional push of the button will provide test session statistics (Figure 12). You can continue to review all of the stored data by continually pressing the timer/counter function button. I did not use an ON/OFF power switch;

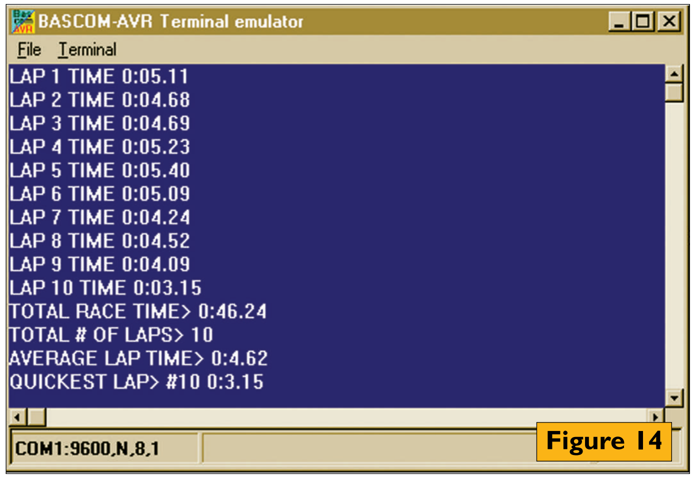


Figure 14

instead, I just disconnected the wire from the 12 V battery to start a new test session.

The DB9 cable seen in Figure 13 is connected to the STK500 serial connector for use with an optional computer interface that can be used to record race data to a file for later analysis. The STK500's RS232 port will print serial data during the lap timing/counting and review processes (Figure 14). This is a convenient way to record those hard-to-believe track times.

Final Thoughts

This project was my first attempt at using a graphic LCD. A lot of the graphics are not really necessary, but they really made the user interface more interesting. Character only displays still have their place in the electronics world, but this enthusiast is sold on graphic displays for all future projects.

A multi-car counter could be created by adding flags of different horizontal widths that intersect the laser above the vehicles. The timer/counter could then be programmed to use flags of varied sizes to respond to the different lengths of time that the beam was broken. Each flag would produce a different pulse width that could be used to distinguish several cars. I will not try this any time soon, but I would be interested in hearing of an ingenious reader's success story.

It was rewarding to have a project that was considered useful by my kids. Their boring RC cars were now fun again because of the added incentive to race the clock. There will be no more doubt as to who the "RC Champion" is in my house! **NV**

Resources

Digi-Key
www.digikey.com
STK500 boards, Atmel controllers, electronic components, and laser modules.

AZ Displays
www.azdisplays.com
Graphic and character displays.

Okaya Electric
www.okaya.com
Graphic and character displays.

MCS-Electronics
www.mcselec.com
BASCOM software.

Tower Hobbies
www.towerhobbies.com
Everything for radio control.

Author Bio

Alonzo Trueland currently works as a PBX programmer for Kennedy Health Systems. He develops microcontroller solutions on a part-time basis; most of his work is in the area of data acquisition and control, but radio controlled projects are his hobby. He holds an FCC license and a certification in industrial control (CET). You can reach him at atrueland@mybluelight.com

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A Really Solderless Breadboard Part 1

by Al Williams

Before solderless breadboards, it was tough to experiment with ICs. If you made a change to a circuit, you had to unsolder or unwrap and risk damaging something, but, even with a breadboard, you need to have the parts you require on hand.

What if you could build any digital logic circuit you wanted, including the software? I don't mean simulating hardware — I mean actually configuring a real piece of hardware to act like any combination of logic gates you need. Making changes would be as simple as a few mouse clicks.

This idyllic scenario is actually a reality, thanks to programmable logic devices (PLDs). These powerful ICs have blocks of logic gates and a programmable way to interconnect the gates. You use special software to describe the circuit you want by either drawing a schematic or using a special language. The software figures what connections are necessary to implement your design and programs them into the IC's flash memory.

For the purposes of this article, I'll use the term PLD to refer to any type of reconfigurable logic device. In practice, PLDs usually refer to devices with a small number of gates. Larger devices are often called Field Programmable Gate Arrays (FPGAs). However, the way you configure the devices is identical, so, for now, just think of them as PLDs.

Just Another Microcontroller?

You might wonder if this is just a microcontroller in disguise. PLDs are actually quite different from microcontrollers. A microprocessor can only do one thing at a time. As a simple example, consider an alarm system that monitors several door sensors, multiple window sensors, and a few smoke sensors. Each class of sensor triggers a different annunciator. A microprocessor can only process these inputs sequentially — while it examines the smoke sensors, it can't read the door sensors.

On the other hand, a PLD doesn't execute a sequential program — if you program an AND gate to monitor five sensors, it reads the sensors continuously. True, this might not be critical for an alarm; however, a circuit monitoring a volatile chemical process, for example, might benefit from a nearly instantaneous response. Besides this, you can often process data at a much higher speed through PLD logic, making PLDs useful for very high-speed projects.

A PLD Project

If you are learning a new computer language, you probably start out with a Hello World program. For PLDs, you need some Hello World hardware. To get you started, I'll show you a simple adder circuit that you can build with a common Xilinx PLD. This PLD is in an 84-pin PLCC package. Although this isn't the easiest package to use in a prototype, it is easier than many other PLDs, which are in high-density surface mount packaging. You can use a PLCC to DIP adapter, if you like, or you can purchase a circuit board (PBX-84) that will allow you to easily mount the chip to a solderless breadboard (Figures 1 and 2).

Of course, you'll want to see something more substantial than an adder, so next month, I'll show you how to use a PLD to convert

Figure 1. The PBX-84 circuit board.

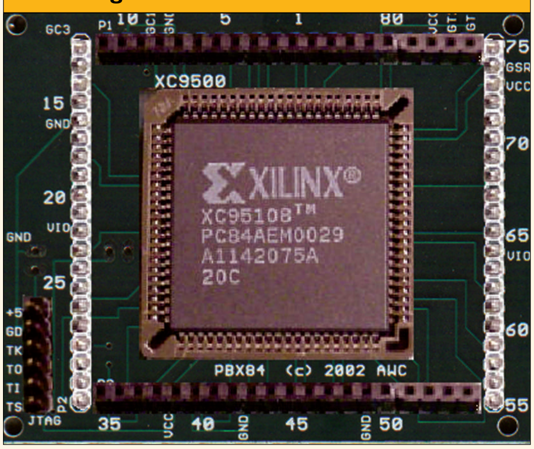
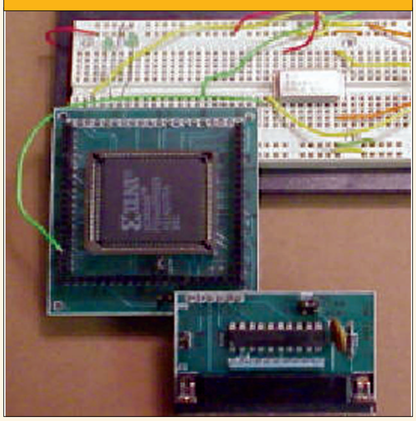


Figure 2. The PBX-84 circuit board connected to a solderless breadboard.



an ordinary oscilloscope into a four-channel digital logic storage scope (Figure 3). Not bad for a one IC project! Before you can tackle something of that complexity, you need to get your tools assembled and learn the basics.

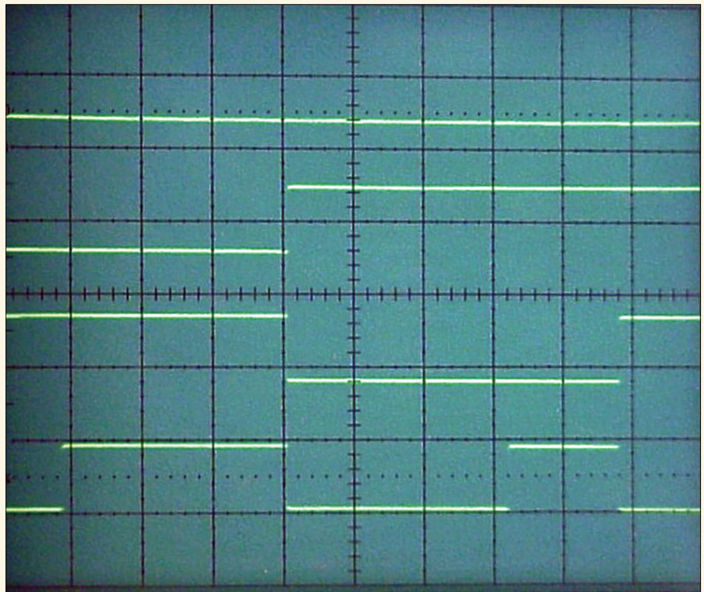


Figure 3. Next month's logic scope in action.

For both projects, we'll use a Xilinx XC9572 IC. If you prefer, you can substitute an XC95108, which has more gates than you need, but is physically the same size and costs only a few dollars more (a 9572 costs under $10.00).

As I mentioned earlier, you'll need some way to build a circuit with an 84-pin PLCC to use these chips. In addition, you need a JTAG programmer. This programmer connects to a PC and allows you to download a program to the chip. Once programmed, the chip retains its configuration until you program it again.

Xilinx will sell you a cable for around $100.00; however, you can easily build your own clone of the cable using the schematics provided by Xilinx on the web (see Resources). If you are using the PBX-84 board, you can also get the matching JTAG adapter that plugs directly into the board.

The most important piece you'll need isn't hardware at all — it's software. Just as you use an assembler or compiler to program a microprocessor, you'll use a special piece of software to configure a PLD. There are several ways you can tell the software what you want it to do. For example, you can draw a schematic and let the software build the circuit you've drawn. This seems appealing when you first start out, since it closely mirrors the way you design and build circuits without PLDs. However, most experienced designers prefer to use hardware description languages (HDLs) — like Verilog or VHDL — to create quasi-programs that the software converts into hardware.

Keep in mind that this software doesn't create a program per se. Although a PLD is programmable, it doesn't execute a program. Instead, the configuration data creates connections between logic cells (known as macrocells) to implement your design. Macrocells are like logic-based Tinkertoys and the program simply connects the pieces together in different ways.

Xilinx provides free software (known as the WebPack) that allows you to enter circuits as schematics or use an HDL (along with several other methods). The steps you take are known as the design flow. In general, developing a PLD design requires several steps:

1. Develop a schematic or HDL module that performs a task.

2. Use the software to synthesize the design into simple logic components (known as synthesis).

3. Simulate the design on the PC using the synthesis data. This is known as functional simulation. If the design does not behave as expected, you'll go back to Step 1 until the circuit seems to behave.

4. Run the synthesis data through the fitter. The fitter actually maps the raw design into the specific device you are using.

5. Simulate the design on the PC using the fitter data (a post-fit simulation). This type of synthesis takes chip-

Pins	Name	Description
8, 16, 27, 42, 49, 60	GND	Ground
22, 64	VCCio	I/O voltage
38, 73, 78	Vcc	Main voltage
28	TDI	JTAG input
29	TMS	JTAG control signal
30	TCK	JTAG clock
59	TDO	JTAG output

Table 1. CPLD Connections for XC9572 or XC95108 in PLCC84 package

specific time delays and other real world factors into account. Again, if the behavior is not what you expect, go back to Step 1.

6. Use JTAG programming software to burn the chip (this can be done while the chip is in the final circuit, if desired). Since you've simulated the device, it should work perfectly. Of course, real world problems can get in the way of this ideal goal, but, overall, it usually works out quite well.

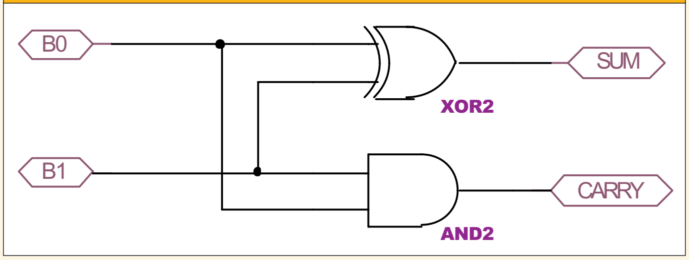
The software simulation is especially powerful. For learning purposes, you don't even need any hardware. Just download the free software, design circuits, and examine their behavior using simulation. It's educational and you can't beat the price!

In Detail

The first step in any PLD design is to capture what you want the device to do using schematics or an HDL. This step is known as design entry. Unless your project is trivial, you'll probably want to partition your design into several modules. For example, if you were going to build a digital clock on a chip, you might plan on having a module that counts in BCD and another that decodes BCD digits to drive a seven segment LED. Another module might generate a time base.

Partitioning has several advantages. First, you can simulate each piece separately and work out the bugs before you try to join all the pieces together. Second, small functional blocks are often usable in multiple projects. Finally, you can mix and match tools to suit your needs. For example, writing a BCD decoder in Verilog is very simple. Drawing it in a schematic form is very complex. So, you might use Verilog to write the BCD digit decoder, but then use a schematic to show how the digit decoders connect to the BCD counter (the counter might also be a Verilog module).

Figure 4. The half adder circuit adds two binary digits, producing a digit and a carry.



No matter what method you use to handle design entry, you'll want to do a quick check of the finished product before you proceed. If you use a hardware definition language, this will check basic syntax. For the schematic editor, the check will look for nodes that are not connected and other obvious mistakes.

The WebPack has several ways you can perform simulation. After design entry, you'll want to use the TestBencher tool to create example input wave forms. Then, you can have WebPack generate the expected output waveforms automatically. At this stage, you'll only be looking for logic mistakes. After you've fixed all of the errors you find, you'll be ready to go on to the fitting step.

Obviously, to perform the fitting step, you'll need to have a device in mind. If your design won't fit, you'll have to modify your design or select a larger device. Another consideration during fitting is the floor plan of the chip. Normally, the first time you fit the chip, the fitter software will select which external pins connect to which signals. However, in some cases, you may want to select pin associations yourself. For example, if you already have a printed circuit board layout, you'll want to force the pins to the proper locations. Before fitting, you can use a special editor to associate signals with pins.

If fitting works without any problems, you'll want to do a post fit simulation and analysis. This serves two purposes. First, it performs a simulation that accounts for propagation delays in the actual chip. Second, it enables you to perform timing analyses to determine things like the maximum clock speed the chip can accept.

Once everything is working, you'll use the programming software to download the configuration into the chip. One nice thing about the CPLDs we'll use is that they hold their own configuration and are electrically erasable. Some larger FPGAs require external memory devices (like EEPROMs) that reconfigure the device every time you apply power. That's generally not the case with the CPLD devices.

All that's left is hardware. Nearly all of the CPLD's pins are for I/O. Table 1 shows the connections you need to make. Notice that there are two separate groups of power pins. One set connects to the core voltage and the other connects to the I/O pin voltage. It is possible to operate at different voltage levels (for example, 3.3 V), but in these examples, I'll use 5 V throughout the system.

So, all you really need are the connections to power and ground. In addition, the four JTAG pins (28, 29, 30, and 59) require connections to the programmer for

configuration. For some designs, you may want to take advantage of certain specialized pins on the IC. For example, there are several global clock inputs. You can use these pins as ordinary inputs or outputs. However, if you assign a synchronous clock input to the pin, special routing circuitry inside the chip can improve the clock skew performance (compared to using ordinary pins for the clock).

An Adder Design

A half adder (Figure 4) is a classic logic circuit. It accepts two inputs and produces a binary sum and a carry; a full adder takes two bits plus a carry from the previous adder. As you can see, the circuit is fairly simple, but you'd need a couple of ICs to wire it up by hand.

To start this design, run WebPack. This brings up the Project Manager. You'll need to make a new project by selecting File | New Project from the menu. You'll see the dialog box in Figure 5. The project name is **hadd**. In the example, I'll use an XC95108 device, although you could select XC9572 if that's the chip you are using. Both devices are much larger than this simple circuit and will work equally well.

I won't use Verilog in this project, but, as a matter of habit, I picked XST Verilog in the design flow box. You could also pick VHDL or EDIF; EDIF is a common format that many third-party tools produce.

Once you've created the new project, you'll see an Explorer-style window to the left of the screen. If you right-click on the **hadd** entry, you'll see a menu. Select New Source from this menu. This will bring up a dialog that lets you add a new document to the project. You can create a Verilog module, a state diagram, or a schematic. In this case, we'll create a schematic named **hadd**.

Once you've created the schematic, you'll save it and use the Tools | Check Schematic menu item to check for obvious mistakes. You can find detailed instructions for using the schematic editor in the online help site (see Resources). Here are a few common pitfalls:

• The input and output markers must touch a wire. You can't place a component and then drop a marker on top of the component. You must draw a small wire stub first.

• If you make a mistake and need to select wires for moving or deleting, pay attention to the toolbar near the top of the screen. If you pick Select Branches, you'll select a wire and everything connected to it. If you pick Select Wire, you'll be able to pick just a specific line segment out of the total connection network.

• Double click the I/O markers to change the node names. You can also name a node by selecting Add | Net Name from the main menu.

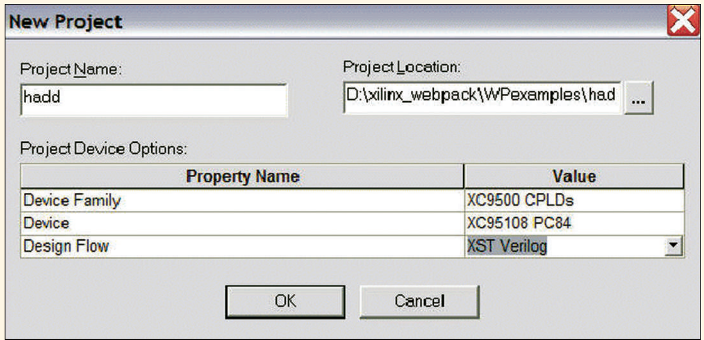


Figure 5. The new project dialog box.

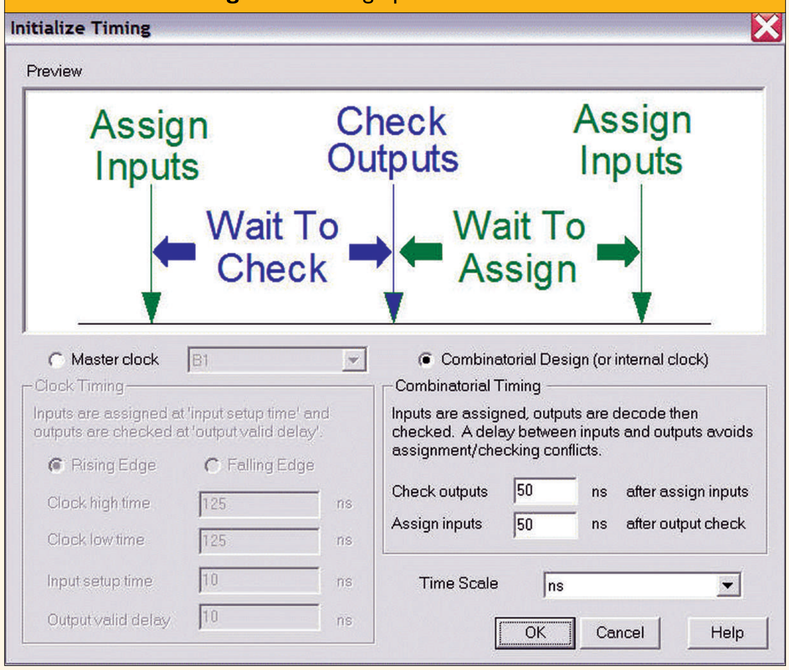
Simulation

If you want to test your half adder, add another source to your project. This time, select Test Bench Waveform as the document type. I called my document **haddtest**. Don't use the same name as the schematic; this can cause problems later down the road. You will want to associate the Test Bench with **hadd**, of course.

The Test Bencher software will ask you to set up a clock (Figure 6). Since the adder doesn't require a clock — it is a combinatorial design — you can ignore the clock setup and just accept the default delays for the combinatorial setup.

After you complete the setup, you can view the input and output waveforms. Of course, you'll want to edit the input waveforms. You can click on the waveform to toggle its value from the mouse cursor forward. You can also use the menu commands to insert clocks or counting values

Figure 6. Setting up a new test bench.



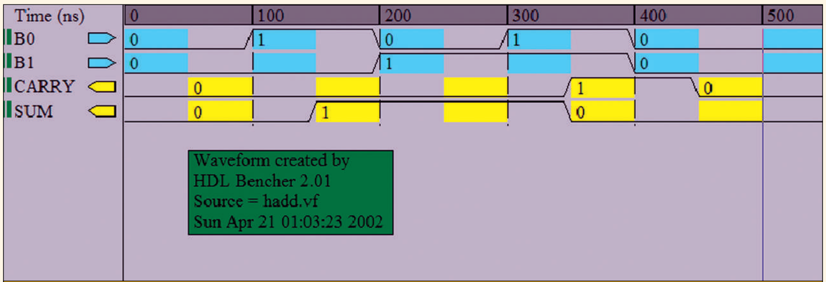


Figure 7. Test bench results.

into the inputs.

At this point, all you've done is define the inputs; the outputs are not correct. You can set the end of the test bench by right clicking on the display at the time you want to set as the end point and select Set End of Testbench from the menu. A vertical blue line shows the end of the test. When you save the test bench, the program may ask you if you want to extend the end of the test.

The easiest way to see the results of the simulation is to return to the Project Navigator and select Generate Expected Simulation Results. This will produce the waveform seen in Figure 7. This waveform confirms that the adder works as expected.

Parts List

R1, R2 - 10K resistor, 1/4 watt
R3, R4 - 470 W resistor, 1/4 watt
S1, S2 - SPST switch
LED1, LED2 — Standard light emitting diode or 5 V LED (if using 5 V LED, omit R3 and R4 and simply connect the LED to ground).

Optional:
PBX-84 circuit board (available from the author)

As a special service, the author has a limited number of special *Nuts & Volts* kits available. Each kit contains a PBX-84 kit, a JTAG programmer kit, an XC9572 IC, and all the parts listed above. Visit **www.al-williams.com/nvkit.htm** for details and to place an order.

Fitting

Since this circuit is so simple, you can depend on the final result working. All you need to do is fit the design into your CPLD. If you are using the PBX84 prototype board, it is handy to put the inputs and outputs on the strip of I/O pins that connect directly to the breadboard. To do this, you'll need to set constraints.

The easiest way to set these constraints is to use the User Constraints selection of Project Navigator (under

Design Entry Utilities). In this menu area, you'll find a selection marked Assign Pins (Chipviewer). Starting this process will launch the Chipviewer, which lets you graphically assign input and output pins to device pins. I set pins 61 and 62 as the inputs (B1 and B2, respectively) and pins 70 and 71 for the sum and carry outputs.

Once the fit is complete, you can use the Configure Device process to program the chip. If you build the circuit in Figure 8, you'll be able to test the results of the adder.

HDL

You might wonder how to define an adder in a hardware definition language. There are several possibilities. Both Verilog and VHDL allow you to define circuits using combinations of primitive gates or by simply describing their behavior. Verilog is very much like C, while VHDL is reminiscent of Ada. Both have their proponents, but I prefer Verilog.

All the details of Verilog or VHDL are outside the scope of this article. However, just to give you the flavor, here's one way to define a half adder in Verilog:

```
module half_adder (B0, B1, CARRY, SUM);
input B0;
input B1;
```

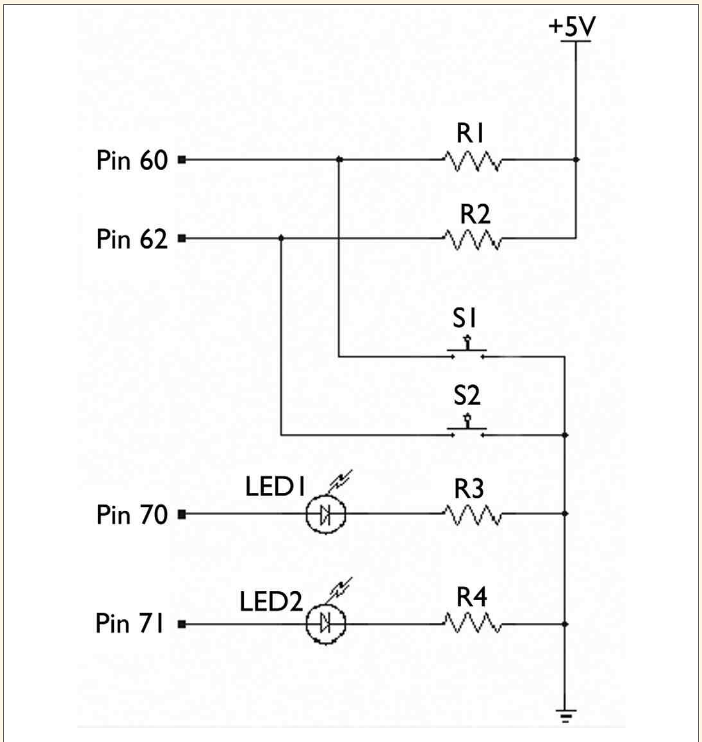


Figure 8. Test circuit for the half adder.

```
output CARRY;
output SUM;
assign SUM = B0 & B1;
assign CARRY = B0 ^ B1;
endmodule
```

This is a straightforward application of the logic gates in the schematic. You can also directly describe the logic gates. In fact, if you click the View Verilog Functional Model process in the Navigator, you'll see this Verilog module:

```
// Verilog model created from schematic hadd.sch

`timescale 1ns / 1ps

module hadd(B0, B1, CARRY, SUM);

input B0;
input B1;
output CARRY;
output SUM;

AND2 XLXI_2 (.I0(B0), .I1(B1), .O(CARRY));
/* synopsys attribute fpga_dont_touch "true" */

XOR2 XLXI_1 (.I0(B1), .I1(B0), .O(SUM));
/* synopsys attribute fpga_dont_touch "true" */

endmodule
```

As you can see, the module simply defines a two-input AND gate and a two-input XOR gate, then connects them, exactly as seen in the schematic. The real benefit to using Verilog is found when you are dealing with things that are easy to describe, but hard to design using digital logic. For example, a four-bit counter would require four flip flops on a schematic; however, in Verilog, it would be as simple as writing this simple line:

```
COUNT <= COUNT + 1
```

In addition to this economy of expression, WebPack provides predefined templates for many common constructs in high level languages; for example, if you need a counter, you can simply select one from the list of templates provided.

Next Time

This will give you something to play with until next month, when we examine the logic scope in detail. In the meantime, try expanding your half adder into a full adder. Then, try building a four-bit adder. Next month, we'll look at synchronous (clock-based) designs. **NV**

Online Resources

PBX-84 breadboard plus tutorials online:
www.al-williams.com/pldhome.htm

The Xilinx home page:
www.xilinx.com

Xilinx documentation:
toolbox.xilinx.com/docsan/xilinx4/manuals.htm

Xilinx gate descriptions:
toolbox.xilinx.com/docsan/xilinx4/manuals.htm

Schematic for Xilinx JTAG cable:
toolbox.xilinx.com/docsan/2_1i/data/common/jtg/fig26.htm

PBX-84 and related discussions:
groups.yahoo.com/group/awcpld

Picture Perfect, Even From Mars

It's not getting as much press as the American explorer robots on Mars, but the European Space Agency's orbiter — the Mars Express — is sending back amazing images, even from its 260 km high orbit. Digital

photographs are taken by the High Resolution Stereo Camera (HRSC) instrument, which contains nine TH7808 linear CCD arrays specially designed by Atmel (**www.atmel.com**). Each array is 5,184 pixels wide and, together, the system provides a standard 10 meter ground resolution with a two meter zoom capability. Here is the kicker — the images are in 3D! This advance in planetary imaging will reveal many of the topographical secrets that are of great interest to astronomers.

Unfortunately, much of the effort since the December, 2003 orbital mission's start has been spent looking for the ill-fated Beagle 2 lander, which disappeared during its atmospheric entry. More information on the Mars Express — plus some amazing 3D images — is available online at **www.esa.int/export/SPECIALS/Mars_Express/**

Have Nanotube, Will Travel — Faster

Physicists at the University of Maryland have fabricated a semiconducting nanotube transistor that holds great promise for the acceleration of semiconductor operation. Operating about 70 times faster than the silicon "wires" used in today's computer chips, carbon nanotubes are gaining increasing research focus. In fact, the industry journal, *Nano Letters*, indicates that nearly every major research university has at least one group studying nanotubes. To make a carbon nanotube, start with a flat sheet of carbon — just one atom thick. Now, roll it into a tube. This unique structure was discovered in 1991 by Sumio Iiijima of Japan's NEC and demonstrates very high electron mobility — the material property that ultimately determines the operating speed of an electronic device. Ideally, nanotubes will be used to connect substrates within semiconductors. If you want to learn more about carbon nanotubes and the research surrounding them, visit **http://nanotube.msu.edu/**

Tech Forum

QUESTIONS

Can anyone help me identify where test point 22 is physically located on a Heathkit Model 4110 frequency counter? I am trying to finish the test sequence in the reference manual.

#4041 **LeRoy Petry**
Lombard, IL

I am looking for a supplier of vacuum tube radio kits. Ideally, my daughter and I would like to build a simple shortwave kit, although I suspect any glowing radio would do. Does anyone know of a reputable kit dealer?

#4042 **Roger**
Triadelphia, WV

Does anyone have a circuit for a solid-state phase converter/inverter? I need to convert 24 VDC to three phase AC to drive 240/480 volt motors. I would also like to vary the frequency from 3 to about 100 Hz. I am currently using an electromechanical solution involving a DC motor driving an AC alternator, but I need to increase the efficiency of the power conversion process.

#4043 **Craig S. Shippee**
South Walpole, MA

I recently needed to have the carburetor on my 1979 Ford Bronco tuned to lower its emmissions. The mechanic used an older-model emmissions analyzer computer to sample the exhaust and then adjust the carburetor so that the percentages of CO_2 and HC were lowered below the state levels, so that it would pass.

How difficult is it to build the sensor needed and interface it to a laptop? I'm thinking of using a CO sensor from one of those home alarms, then hooking it up via the parallel port to the laptop, and writing some software to show the numbers. Can this be done for less than buying a diagnostic computer on the open and/or used market? I already have the laptop, am familiar with circuit design — both digital and analog — plus, I can develop the software. What I lack is the finer details of the sensor operation and how emmission analyzers work.

#4044 **Andrew L. Ayers**

Many years back, there were ads in the electronics magazines about converting a TV to an oscilloscope. Does anyone remember how this was done?

#4045 **Francis Hillibush**
via Internet

I need a timer for a remote feeder, where no AC power is available. I must activate the feeder once or twice a day for a one minute period while I am away for several days. This will be a broadcast feeder wheel.

#4046 **René Plouffe**
Niagara Falls, Canada

I am looking for a schematic to build a 12 VDC pulse charger (to eliminate battery sulfating). I should be capable of charging up to 25 A.

#4047 **Antonio Anzevino**
Wappingers Falls, NY

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

Send all material to *Nuts & Volts Magazine*, 430 Princeland Court, Corona, CA 92879, OR fax to (909) 371-3052, OR email to forum@nutsvolts.com

ANSWER INFO

• Include the question number that appears directly below the question you are responding to.
• Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
• Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
• Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO
To be considered

All questions should relate to one or more of the following:
1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions

• No questions will be accepted that offer equipment for sale or equipment wanted to buy.
• Selected questions will be printed one time on a space available basis.
• Questions may be subject to editing.

Helpful Hints

• Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
• Write legibly (or type). If we can't read it, we'll throw it away.
• Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

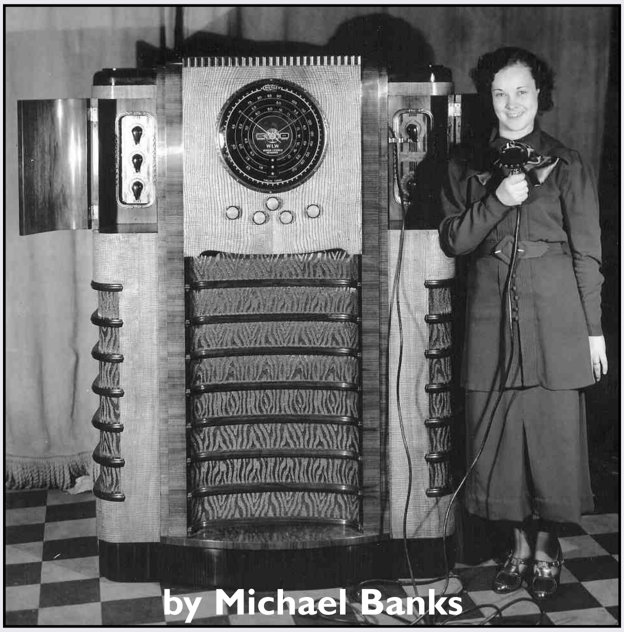
ANSWERS

[1044 — January 2004]

I'd like a circuit that can capture theater or TV scene breaks based on sudden variations in screen light. I tried this with an LDR and a few transistors driving a small relay linked to a counter, but the response was not fast. Using a phototransistor, I got vertical sync pulses instead of scene breaks. I did find some capture ideas based on

The Colossus of Radio

Crosley Radio Corporation's 1936 "WLW Model Super-Power Radio Receiver"



by Michael Banks

In 1935, the Zenith Radio Corporation produced a stunning radio receiver called the Stratosphere model 1000Z. The set used 25 tubes and three loudspeakers — more than any other radio to date. An amazing (for the time) 50 watts drove its three speakers — one 6 inch dynamic high-frequency and two 12 inch dynamic low-frequency speakers.

Standing 50-1/2 inches tall, the Stratosphere sold for $750.00 — more than many automobiles; in comparison, a new Ford cost $652.00. At that price, it's no wonder that only about 350 sets were produced during the four years that the Stratosphere was offered.

This achievement impressed Powel Crosley, Jr. — the President of the Crosley Radio Corporation — who praised it as a fine example of quality in radio construction, but it used "only" 25 tubes and three speakers! Crosley — who also owned the 500,000 watt powerhouse radio station, WLW — was inspired to surpass Zenith by bringing the world the largest and most powerful radio receiver yet known.

A close friend of Commander Eugene MacDonald — President of Zenith — Crosley may have taken the Stratosphere as a light-hearted challenge. That aside, Crosley later said, "It is fitting that the owner of the world's most powerful radio station make the world's greatest radio receiver."

Crosley's engineering and marketing staff urged him to forget the idea. They felt that it was an impractical exercise from an engineering standpoint and that the market for such a radio — if one existed — would be miniscule. Crosley, however, was not easily discouraged and, as one employee put it at the time, "It is characteristic of Mr. Crosley that he is a good salesman — enough so to win his point in an amiable manner." Of course, the fact that Crosley owned the company had some bearing on the matter.

Surpassing the Zenith Stratosphere turned into a bigger project than anyone had expected. Many engineering conferences were held throughout the winter months, some of which included Crosley's advertising, sales, accounting, and purchasing departments. To aid with speaker selection and the acoustics involved in cabinet design, the Chief Engineer of the Jensen Radio Manufacturing Company was retained as a consultant; Jensen is the same company that now manufactures speakers.

Out of the numerous meetings and Crosley's imagination came the basic specifications: the radio would be a superheterodyne receiver with no fewer than 30 tubes, six loudspeakers, four chassis; a suitably

Title Picture. Front of Crosley Radio Corporation's WLW Model Super-Power radio receiver. Features included multiple tuning, volume, fidelity, and tone controls, as well as a public address system.

impressive cabinet would house it. More intricate than any set ever built, it would naturally have the highest possible quality and richness of tone.

The set would be called the "WLW Model Super-Power Radio Receiver." This name was chosen by Powel Crosley, Jr. because it was, as a spokesman later said, "symbolical of the great 500,000 watt broadcasting station — the most powerful in the world." (Crosley never missed an opportunity to use one product to promote another.)

Early in the spring of 1936, Crosley assigned the task of designing the radio to one of his engineers, Amyle P. Richards. The 31-year-old engineer had his doubts about the project at first. "The logic of the situation was not at once apparent when Mr. Crosley gave the orders for construction," Richards was quoted as saying. "From the cost angle — engineers cannot ignore costs — it was perhaps the best plan, but from the angle of sheer engineering skill, it was not a desirable plan, but it also must be understood that the plan here adopted was necessarily in accordance with the wishes of Mr. Crosley."

Although his engineer's mind questioned the project, Richards enjoyed the challenges that the project presented. In fact, he later wrote that he, "enjoyed every minute spent on the creation of this receiver and welcomed the responsibility of making it a commercial possibility."

The project involved four basic segments: a variable radio frequency or pre-selecting amplifier, an intermediate frequency amplifier, a pre-audio amplifier, and the power supply. Richards designed a separate chassis for each segment. Three audio channels handled low-, medium-, and high-frequency ranges, assisted by a triple-tuned transformer.

Every feature that could be built into a radio was included. Automatic Volume Control (actually gain control — then a relatively new idea) minimized the undesired volume increases that would occur when a station's signal power suddenly increased or when a listener tuned from a distant station to a more powerful, local station. Automatic Frequency Control prevented drifts from the tuned frequency. By increasing or decreasing the volume to match variations in signal modulation strength, an Automatic Volume Expansion feature compensated for the natural or intentional variations in the volume of the music or other programming that was being broadcast.

In its completed form, the WLW Model Super-Power Radio Receiver indeed surpassed the Zenith Stratosphere model. It had 37 tubes, six speakers, and 75 watts of power. The cabinet stood 58 inches tall, 42 inches wide, and 22 inches deep. Everything inside the cabinet that could be was chromium-plated. The transformer coils, tubes, and speaker frames were finished in black and

Figure 1. The rear of the Crosley Super-Power set. Everything that could be was chromium-plated.

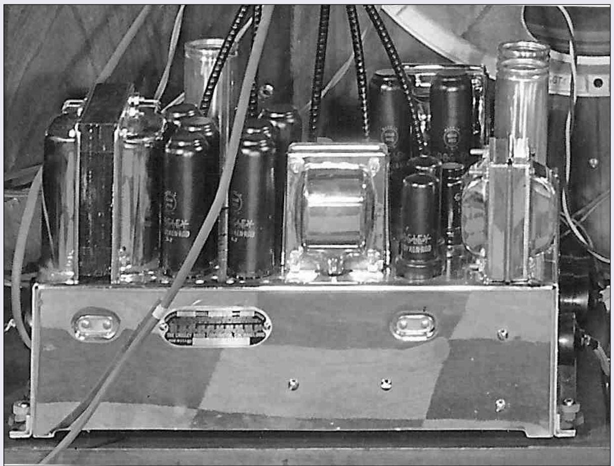


Figure 2. Close-up view of one of the four electronics chassis inside the WLW model receiver.

each chassis had its own serial number plate.

The speaker bank consisted of three high-range tweeters and two 12 inch "mezzo" or mid-range speakers, plus an 18 inch "auditorium" speaker for the low-range, with the voice coil circuits phased for maximum quality sound reproduction. The speakers were focused in three different directions and the low-range speaker sat in a special cushioned mounting to prevent cabinet resonance. Because of weight considerations, the WLW model was shipped with the speakers uninstalled. (The 18 inch speaker alone weighed 85 pounds.) With the speakers installed, the WLW Model Super-Power Receiver tipped the scales at 475 pounds.

In keeping with the Crosley tradition of adding something extra to everything the company built, the WLW Model radio receiver featured a public address system and a microphone. The microphone was a 4 inch crystal type, attached to the set by a 25 foot cord. The microphone's input could be switched to any or all of the set's three audio channels. A two-way switch either cut out the radio entirely or allowed the microphone's input to be blended with a radio program. This was probably the first account of a radio being equipped with a PA system. The designer rated it as having sufficient volume to address a crowd of 10,000.

The receiver could reproduce the entire range of audible sound — from 20 to 20,000 cycles per second. Its tuner brought in every frequency from 540 to 18,300 kilocycles, which, at that time, encompassed the commercial broadcast, police, amateur, and ship bands, as well as foreign stations.

Such an impressive radio demanded an impressive cabinet. A modern style was chosen and seven different types of wood went into the cabinet's construction. A grille cloth designed especially for the Crosley WLW model completed the stunning exterior; the fabric's design was a classic flame motif that was popular in tapestry and furniture upholstery, as well.

Every imaginable user control was included. An eye-catching 12 inch "airplane-style" tuning dial was mounted at chest level and beneath it were two volume controls (one for low and middle frequencies and the other for high frequencies), two tuning knobs, and a special fidelity control that incorporated the ON/OFF switch.

The fidelity control allowed the user to select from five preset frequency ranges. The "Normal" selection passed only the middle range of audio frequencies. A "High Fidelity" selection — ideal for listening to music — increased the response for 40- and 4,000-cycle frequencies by several decibels. A "Mellow Tone" setting made whatever radio program was on sound as though it were issuing from the inside of a large barrel. This was accomplished by suppressing the high-frequency response. A "Bass" selection accentuated bass response and cut off high frequencies. The final setting offered by the Fidelity Control — "Noise Reducing" — emphasized the high- and low-frequency response. A mechanical display to the right of the tuning dial's center indicated which fidelity setting was in use, including OFF.

The fidelity control feature was apparently popular only briefly in the mid-1930s. It probably added too much to a radio receiver's cost to appear on any models, except for the high-end ones. Also, many radio owners may have found it too complicated to use.

Tuning was accomplished with two knobs — one for fine adjustments. The knobs turned two clock-like sweep hands (one short, one long) on the dial's face. Appropriately, the outer rim of the dial was marked with the numbers 1 through 12, just like a clock face. The clock numbers and sweep hands comprised a mnemonic device for remembering station settings. A station tuned in with the short hand pointing at 10 and the long hand pointing at 3 on the dial might thus be remembered as "10:15." The feature was called "Timelog Tuning."

A mechanical display to the left of the dial's center showed the name of the band that was tuned in.

Three tone controls were set in their own panel on the left side of the cabinet — one each for bass, mezzo, and treble control. The microphone input and controls were on the right side of the cabinet. Hinged, curving wood panels covered both sets of controls.

An external feature of special interest was a visual tuning indicator, which was Crosley's answer to RCA's "Magic Eye" indicator. This indicator was incorporated

into the Crosley trademark at the top of the tuning dial. The trademark consisted of the name “Crosley” with a bolt of lightning passing through it. The lightning part of the logo was cut out and a neon tube was installed behind it. The intensity of this tube’s glow increased or decreased as the voltage in a DC amplifier varied. The effect produced when a station was tuned in was a lit, orange-red flash of lightning through the Crosley trademark. The stronger the signal that was being received, the brighter the flash of lightning would be. So, tuning into WLW would make the most of this feature!

The WLW Model Super-Power Radio Receiver was announced on November 25, 1936. The press release for the set was headed, “Here is the Colossus of Radio,” and offered a breathless listing of the components and capabilities of this new wonder of the radio world. The receiver was presented as both powerful and practical. “In spite of the fact that it has a tremendous volume range with a maximum output of 75 watts,” the release explained, “this gigantic receiver can be toned down to arm chair or living room levels and still retain all the original expression of the music as rendered in the studios.”

The set made for excellent PR and Powel Crosley, Jr. surely had a laugh over it with his friend, Eugene MacDonald at Zenith.

The set was priced at $1,500.00. There is no record of how many of the WLW Model Super-Power Radio Receivers were built, but the first sale was made to Wheless Gambill — a Crosley distributor in Nashville, TN. Powel Crosley, Jr. certainly put one in his home and probably sent one to Eugene MacDonald at Zenith.

Designer Amyle Richards received a bonus of sorts for his work. He had earned a Bachelor of Science degree in Electrical Engineering from the Oklahoma Agricultural and Mechanical College in 1927. In 1939, he submitted a thesis on the WLW Model receiver to the college’s engineering department; on the basis of the project, he was granted a Professional Degree in Electrical Engineering. **NV**

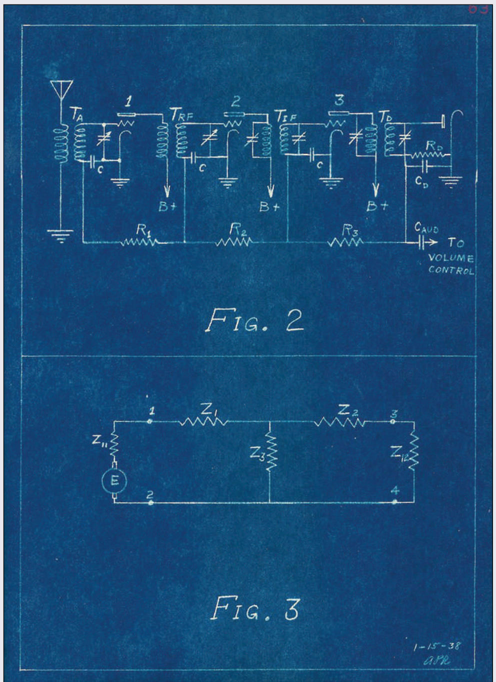


Figure 3. RF tube schematics and impedance network.

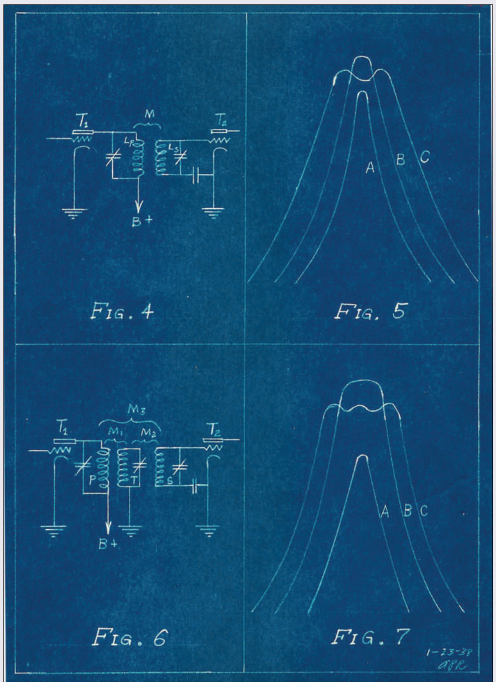


Figure 4. Tuned transformer schematics and coupling.

Those Mysterious Call Letters

The call letters by which radio stations identify themselves are a never-ending source of puzzlement. A few have a readily discernable reference to ownership (WABC or WNBC) or actually form a word (WARM). Most, however, were arbitrarily assigned, with no meaning intended.

One rule was established early on, in 1914, but that was only so stations could be identified by country. For no reason in particular, it was decided that all US radio station call signs would begin with W or K to distinguish them from, say, Canadian radio stations, which begin with the letter C. In 1923, it was further determined that stations west of the Mississippi would begin with K and those east of the mighty river would begin with W. A few stations with out of place call signs, like Philadelphia’s KDKA, were left as they were.

Some call signs were granted by request. For example, WKRC in Cincinnati, OH was originally owned by Kodel Radio Corporation. WSM, in Nashville, TN was originally owned by a life insurance company and WSM was requested as an anagrammatic fit for “We Shield Millions.”

WLW, however, is one of the arbitrary call signs. The applicant was Powel Crosley, Jr., on behalf of the Crosley Manufacturing Corporation. The letters WLW fit neither of these. Had Crosley thought to request a specific call sign, the station might have been WPCJ or perhaps WCMC. He might even have requested WCIN (for CINcinnati), but he didn’t and so he was handed WLW.

Of course, there have been attempts to assign meaning to the letters WLW over the years. “Whatta Lotta Watts” was fitting in the 1920-30s, as the station went first to 50,000 and then to 500,000 watts. Any number of WLW employees in the old days (and perhaps now) might tell you that WLW stands for “World’s Lowest Wages.” Other possibilities are: “We Love Watts” and “World’s Largest Wireless.” Still, the fact remains that WLW is an arbitrarily assigned call sign.

Approaching the Final Frontier

Near Space

An Introduction to the Amateur Near Space Program — My Near Space Program

It's safe to assume that most of you are interested in space exploration. In fact, most of you would already have built and launched your own spacecraft, if not for the high cost involved. We have the interest in space exploration, but we're stuck in a lurch. It seems to be a pent up demand with almost no available outlets; however, this column will show you how to create and operate an amateur near space program — the poor man's space program — right out of your house.

Real space programs are unaffordable because they use specialized launch facilities, a global communication network, space-rated materials, and dangerous rockets. An amateur near space (NS) program is affordable because it uses open fields, amateur radio, Styrofoam, and weather balloons.

Now, this is not some watered-down, pretend, science fiction fantasy. Instead, think of an amateur NS program as the garage band version of a national space program. In your amateur near space program, you'll build functioning models of spacecraft and launch them on missions into a space-like environment — and it's cheap! Compared to the cost of building and launching a professional spacecraft, yours will cost less than $5.00 for every $1,000,000.00 spent in construction and will be launched for 1/1000th the cost, per pound. You can now afford to be a spacecraft engineer and perform experiments in an absolutely lethal environment. Amateur NS is a high-tech hobby unlike any other you've seen.

The first amateur NS flight occurred on August 15, 1987, when Bill Brown (WB8ELK) launched an amateur radio on a helium-filled weather balloon. Since that time, amateurs have flown several hundred missions. Today, close to one dozen groups and over 100 people are involved in amateur NS programs. The average participant is a licensed amateur radio operator who makes launches his or her hobby. Most people are involved for the fun of launching and tracking a payload which is capable of reaching altitudes in excess of 100,000 feet; some are primarily interested in the amateur science aspect.

The Typical Amateur Near Space Mission

The NS craft consists of one or more modules filled

An EOSS chase vehicle. It carries a portable weather station, along with tracking equipment. It can communicate with other chase teams, find directions, and track mission progress with APRS. Photo by John and Deb Knapp.

Getting ready for launch. The stack on the left is about to be raised on lanyards, while the one on the right has already been raised. These two flights carried their payloads to altitudes of 98,000 and 99,000 feet.

with avionics, possibly one or more experiments, and a pre-deployed parachute. The NS craft is carried by a load line and a helium-filled weather balloon — collectively called the launch vehicle. The prep and launch can be accomplished by six people in less than an hour. Many times, the prep and launch takes place just prior to sunrise, before the winds have a chance to pick up.

The climb out after launch is very gentle. There is no significant stress on the airframe or experiments (unlike rocket launches). Because of the low stress launch, styrofoam is a major construction material. The ascent rate of the NS craft is on the order of 1,000 feet per minute. This means that the ascent time to balloon burst is less than two hours. The weather balloon expands in volume as it ascends and, depending on the balloon, it can reach a diameter from 20 to 30 feet before bursting. If you know where to look, you can see the balloon with the unaided eye, even at an altitude above 100,000 feet; it looks like a faint star in the daytime sky.

At balloon burst, the recovery parachute opens automatically and the module begins its descent. The initial descent rate can be greater than 6,000 feet per minute at high altitudes because the low air density creates very little drag. As the NS craft gets closer to the ground, the air density increases and the descent slows to a safe landing speed of about 10 feet per second. A module usually takes about one hour to reach the ground.

Examples of Experiments

One amateur NS organization — the Edge of Space Science (EOSS) — has launched missions in support of professional organizations. However, most amateur missions are limited to amateur science. For examples of possible experiments, see my article in the March 2004 issue of *Nuts & Volts*.

Future Experiments

Many other experiments are possible on amateur missions; in future columns, I will provide more details — and results — of experiments. How about designing and testing a Geiger counter telescope? Life science experiments are possible by carrying bacteria and spores into NS. Elementary school students can practice the process of science by planting seeds that were exposed to NS conditions (near vacuum, cold temperatures, low air pressures, and increased UV flux) and comparing the results with controls. A long-term science project becomes possible when students harvest the seeds of exposed plants and send them up on future flights. Sterile petri dishes can be opened in NS in an attempt to

A BalloonSat after recovery. BalloonSats do not carry independent trackers, but rely on the NS craft they are attached to. BalloonSats are designed and built by university students as part of the Space Grant Consortium.

collect bacteria and spores residing in the stratosphere. Life support systems for insects can be developed and tested. (Please do not launch animals more complex than insects into NS; in addition to being inhumane, there are many laws concerning treatment of and experiments with animals.)

Along with science experiments, engineering tests can also be performed. Will a LEGO robot function properly on Mars, with its frigid air temperature and low atmospheric pressure? Carrying a LEGO robot to an altitude of 100,000 feet is one way to find out (and fun, to boot). Imagine young students getting a photograph or video tape of their LEGO robot operating at 100,000 feet with a curved, blue Earth, and black space as its backdrop!

Starting Your Own Amateur Near Space Program

I hope you're finding amateur NS to be as interesting and exciting as I do. It's really easy to start your own program. In less than a year, you could be launching your own module and collecting fantastic results. Just imagine the photographs that could be hanging on your living room wall next year. To get started, you need to accomplish the following tasks:

- Earn an amateur radio (ham radio) license or recruit hams
- Practice tracking objects with APRS
- Become familiar with FAR 101
- Build an airframe
- Build avionics
- Sew or purchase a recovery parachute
- Build one or more experiments
- Assemble the balloon filling equipment
- Learn to use the LiftWin and BallTrak programs
- Practice launch procedures
- Set a launch time and place

While it's not absolutely necessary to earn an amateur radio license, it does make it easier. Without your own license, you're dependent on others to test your NS craft and its experiments for you. The good news is that you no longer need to learn Morse Code to get an amateur radio license.

APRS is the Automatic Packet Reporting System. Packet radio is a method for transmitting and receiving digital data over amateur radio. Think of it as using a modem over the radio rather than over a telephone line. APRS takes digital packet radio data and displays it in a graphical format on a laptop or PC. The position of your

Some launches, just after the balloons have been filled. Until they are tied and taped shut, the balloons are secured to 120 lb. helium bottles to anchor them while the rest of the NS craft is being prepped.

A beautiful sight — a spacecraft after its mission. APRS reports the landing position to within 100 feet. Recovery crews only had to follow their GPS receivers until the parachute was sighted.

NS craft is displayed on a moving map that is stored in software. Your NS craft is displayed, in addition to your crew, as they chase it, in addition to all of the roads in between its location and yours.

FAR 101 is the Federal Aviation Regulation, Chapter 101. FAR 101 is the bible of balloon launches (along with rockets, tethered balloons, and kites). The Regulations look intimidating, but is actually quite simple, as long as you limit the weight of the NS craft. If you follow the list of limits which follows, there will be no required permission to launch.

- A total weight of 12 pounds for all the modules in the NS craft
- No single module weighing more than six pounds
- No module with a side smaller than six square inches
- Use safe launch procedures and a recovery parachute
- No launching from restricted air spaces without the permission of the owner

FAR 101 is a reasonable attempt to share our air space resources between commercial aircraft, private pilots, and amateur science. To be a responsible user of air space, filing a NOTAM (notice to airmen) before you launch is advisable. Accomplishing this requires only a simple call to a toll-free phone number.

In addition to this column, directions for constructing airframes, avionics, and balloon filling equipment are available by contacting me or other NS groups. The fastest and simplest NS craft to obtain is a reusable lunch bag carrying an APRS tracker based on a Tiny Trak III. Check my article in the February issue of *Nuts & Volts* for details.

Parachute directions are available from the same sources. An alternative to making a parachute is to purchase an amateur rocket parachute and modify it for your use.

LiftWin and BallTrak are programs written specifically for the amateur NS community. Copies of the programs can be downloaded from the EOSS website (**www.eoss.org**); there is no cost for using this software.

Are you still as excited by amateur NS as I am? This column will show you the ropes. Everything from building airframes, trackers, flight computers, and recovery parachutes will be explained in future columns. I'll provide directions for assembling balloon filling equipment and explain prep and launch procedures. Flight predictions and some of weather's effects on flight will be covered, as will putting together a launch and recovery crew.

Perhaps the most exciting aspect of the program — designing experiments and analyzing their results — will

also be featured.

In this column, I want to share the experiences of amateur near space programs with those who are still deciding if they want to begin their own program. I also want the science results of flights to be shared with those readers interested in analyzing data.

I'll use this column to make items which have been exposed to NS — like plant seeds — available to students and their teachers. Suggestions for analyzing data — and, I hope, a few lesson plans — will also be included. New techniques for old problems are another topic I will cover. I'll report on professional organizations involved with NS.

Since I'm a high school teacher, I spend a lot of time traveling. I plan to spend some of that time visiting other groups and launching with them. You'll get to read about some of my NS adventures. Every article will help you build or operate an experiment or analyze the resulting data.

Onwards and Upwards, Your Near Space Guide. **NV**

More Near Space Web Resources

A list of amateur groups can be found in "Near Space, Part 1" in the February 2004 *Nuts & Volts*; however, I accidentally left out one group (sorry, Harry). If you're in the OK region of the US, then talk to Harry Mueller (KC5TRB) and the Oklahoma Research Balloons (ORB). His website is **www.gbronline.com/harrymue/orb/**

The KNSP website listed in my February article is for my former program. The website is still available online, but there are no more launches from it. On the other hand, the KNSP Email list is still active and managed by Mark Conner (N9XTN); it is the primary information source for Midwest amateur NS launches.

Ralph Wallio maintains a website of theory and current mission records. Check his website out for a flavor of the state of the art and what groups are accomplishing. His website is **http://users.crosspaths.net/~wallio/**

About the Author

L. Paul Verhage is an electronics teacher at the Dehryl A. Dennis Professional Technical Education Center in Boise, ID. He began working in the amateur near space field in 1994 and has accomplished over 40 missions. His book, *Amateur Near Space with the BASIC Stamp 2p*, will be published this year by Parallax.

TechKnowledgey 2004

Events, Advances, and News From the Electronics World

Advanced Technologies

Life Discovered on Mars!

The Spirit Rover confronts a life form on a rock. Courtesy of NASA Jet Propulsion Lab.

It is widely known that, on February 6, NASA's Mars rover, Spirit, experienced operational problems related to data-management glitches in its flash memory.

What has not been officially announced, however, is that, after a restart and reprogramming, Spirit transmitted some startling photos back to Earth that prove the existence of life on the Red Planet. Several of the images showed an insect-like creature sitting atop a rock. NASA has unofficially named the rock "Adirondack" and refers to the creature simply as "Stinky."

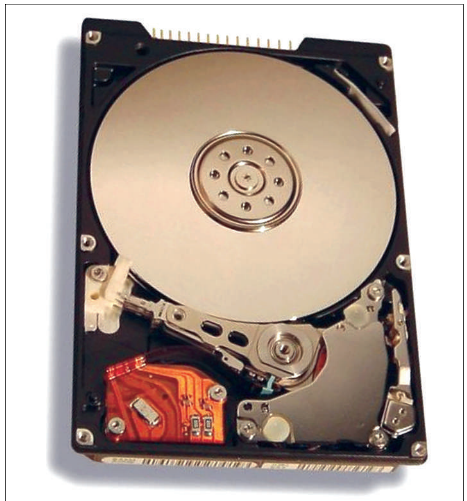
According to a NASA Jet Propulsion Lab spokesperson, who requested anonymity, "It was quite a surprise and we are not quite sure how to break the news to the public. At first, we thought there must be some kind of a mistake. How could such a thing exist up there? For example, the creature appears to have wings, but the Martian atmosphere is really too thin to allow practical flight with such a short wingspan. Then we thought, well, a platypus has a duck bill, but it doesn't go 'quack.' So, why not a Martian creature with wings?" He continued, "The big question is how the thing finds sustenance; that is, what does it eat? We're continuing to study the photos to see if there are any clues."

The discovery occurred while Spirit was scratching Adirondack with a steel-bristled brush to see what was beneath a crusty layer of dust (a process that has led to the amazing discovery of a dusty rock). The creature appeared on the 37th Martian day of Spirit's quest (a Martian day last approximately 40 minutes longer than an Earth day), but has not been seen since then. Continuing information on the Mars rover project is available at **http://marsrovers.jpl.nasa.gov/home/**

Computers and Networking

Virtual Ramdisk Offers Flexibility

One of the venerable — but now less popular — computer utilities is the ramdisk, through which the operating system is "fooled" into thinking that a large chunk of RAM is actually a hard drive. The advantage of a ramdisk is that the time required to access data is much shorter, making it wonderful for database sorting and other data-intensive functions. The primary disadvantages are: (1) Data written to a ramdisk is lost when the machine is shut down. (2) Most computers have a relatively small amount of RAM available for this purpose.



The VRD250X Virtual Ramdisk provides static data storage and extended capacity. Photo courtesy of Chihita Technologies.

These drawbacks, however, have been overcome by the VRD250X Virtual Ramdisk from Chihita Technologies (**www.chihita.com**). The VRD250X works much like a traditional ramdisk. It also "fools" the operating system, in this case, convincing it that a rotating magnetic platter is actually a block of RAM. There is something of a sacrifice in terms of seek time, which drops to 8.5 ms on average, but an 8 MB buffer option can substantially increase performance. The device offers massive data capacity, as compared to the amount of RAM available in most PCs — up to 250 GB. Best of all, the VRD250X fits in your computer's spare hard drive slot and employs the same connectors. Street price for the VRD

— which will be available by the time you read this — is rumored to be less than $500.00.

Toxic Computer Waste Problem Solved

As more and more computer systems have become obsolete and ready for the scrap heap, local, state, and federal regulators have grown more sensitive to the hazards of potentially toxic substances used in the manufacture of such equipment.

For example, a typical CRT monitor can contain as much as 9 lbs. (3.4 kg) of lead. Printed circuit boards contain cadmium, beryllium, flame retardants, and other chemicals that can contaminate the atmosphere and water.

Other high-tech devices can also contain mercury, hexavalent chromium, and other dangerous compounds.

To avoid the typical cost of $30.00 per unit to dispose of used computer CPUs, many companies have cleverly donated the items to local schools, thereby transforming an expensive disposal liability into a nice tax write-off and a public relations triumph. However, the recipients are getting wise and have become increasingly unwilling to be used as dumpsters.

As a result, many information technology companies have resorted to dangerous disposal practices, such as sending scrap equipment to developing countries, burying it in secret sites around the US, and paying shadowy disposal companies to haul it away.

Fortunately, the problem seems to have been solved by the folks at Stellar Smooch Tuna Corp. (**www.cleenfish.com**), who are urging owners of obsolete computers to ship the old units directly to the Smooch canning facility in Ketchikan, AK. In what appears to be a brilliant solution, the metal computer cabinets are recycled into cans for Stellar Smooch's products. The rest of the machinery is tossed into the company's fish processing facilities, where it is burned to smoke tuna and salmon. The smokers are completely self-contained, so no toxic fumes escape into the atmosphere.

According to company president Ryan Schmooze, "This is a great program. Not only do we get these chemicals out of the environment, we are using a substantial portion of the materials as fuel, which saves money.

It's true that some of the chemicals end up in the fish that's eaten by consumers, but we're keeping it below toxicity levels that are likely to be considered deadly. The result is that the substances are harmlessly absorbed into consumers' bodies, where they permanently attach themselves to neural and muscle cells, bone marrow, the cerebral cortex, and so forth, thus preventing them from polluting our air and water. When the person expires, the chemicals go right into the casket, so they remain isolated virtually forever."

For details on how you can participate in the program, please contact the company directly.

Circuits and Devices

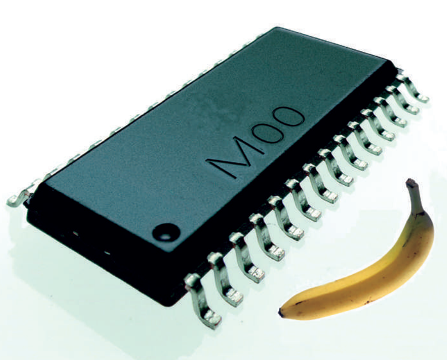
IC Simulates Classic Audio

If you miss the warm, fuzzy sound of vinyl recordings — with the associated hisses, cracks, pops, and other overdub distortions — you're in luck. Sonorous Devices, Inc., (**www.sonorousdevices.com**) has introduced the NG1969 analog IC, a dual-channel noise enhancement chip that employs a reverse filtering concept that actually brings out the background noise. It also offers user-selectable sound enhancement that simulates the sound of a needle dropping into the record groove, various types of dirt in the grooves, and even the sound of the needle being dragged across the surface of the record.

In addition, it can generate the friendly 60-cycle hum that was typical of some vintage Dynaco tube amplifiers.

In designing the chip, Sonorous engineers purchased hundreds of used LPs and studied the auditory effects of various substances that were found in the grooves. These included dust, dried beer and wine, cigarette smoke, pepper gas, K-Y jelly, and shag carpet fibers. The result is a sound that has not been heard since the early 1970s. The chip, which can be designed into most receivers and amplifiers, employs a reverse Dolby®-like technique that discriminates between the musical data and distortions, reduces the levels of the former, then amplifies both. This creates up to 25 dB of auditory enhancement. The NG1969 runs about $8.50 in lots of 1,000. Now, you just have to track down some Jefferson Airplane CDs and a shoehorn to help you get into your old hip-huggers.

World's Largest IC Introduced



The MooCow6808 microcontroller tips the scale at nearly 8 oz. Courtesy of Moo Electronics.

The new MooCow6808 microcontroller from Moo Electronics (**www.mooelect.com**) is billed as the world's largest integrated circuit. With a length of 16 in. (40 cm) and a dry weight of nearly 8 oz. (230 g), it appears to live up to the claim. According to Moo VP of Marketing Hank Tipper, "We looked around and noticed that Intel and AMD have products that are faster, cheaper,

and more reliable than ours and we figured that the only way we could beat them is in terms of greater size. This approach does have drawbacks in terms of operating speed, power consumption, and so forth, but we use marine plywood as the dielectric between layers of copper foil. This means that the devices can actually be repaired using standard carpenter's tools. You don't have to throw them away when they fail. Plus, they can be soldered into a circuit using a propane torch and inexpensive acid-core solder."

The 6808 offers 16 bytes of internal RAM, a 60-Hz bus frequency, and runs off 110-V half-wave rectified DC current. Suggested applications include control of high-voltage metronomes, cement mixers, and Yugo fuel pumps.

The wholesale price is $6.00 per unit, plus $8.95 shipping and handling.

Industry and the Profession

Pending Legislation Covers Batteries, Schematics

Late in March, US Representative Otis Spudbugger (D-NY) introduced legislation that would require a major revision in the way electronic schematics are drawn. In a press release, Rep. Spudbugger noted, "I was putting a new set of batteries into my CD player the other day and it occurred to me that every drawing I've ever seen shows electricity coming out of the positive end of the battery and going back into the negative end. That doesn't make any sense. Electrons are negatively charged, so it should go the other way. I checked it out and I was right. It looks like all of our textbooks and electrical diagrams are wrong. This is a scandal that will shake the electronics industry from top to bottom. We've got to find out who is behind this."

Provisions of the pending legislation would require all electronic schematics drawn after December 31, 2004, to show electricity flowing from negative to positive and all batteries would have to be labeled in the reverse of the traditional manner. Citing the importance of the measure, Rep. Spudbugger noted, "One little mistake and we could have all of our electrical equipment running the wrong way. Imagine your electric toothbrush putting crud back onto your teeth instead of cleaning them. Also, if you put the batteries in a flashlight the wrong way, it could suck all of the light out of the room. It's just too dangerous to continue doing things the same old way." You can express your opinion by sending a message to OtisSpudbugger@yahoo.com

Until next month, I hope you've enjoyed the April 1, 2004 TechKnowledgey column! **NV**

by Jon Williams

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

Speak the Speech

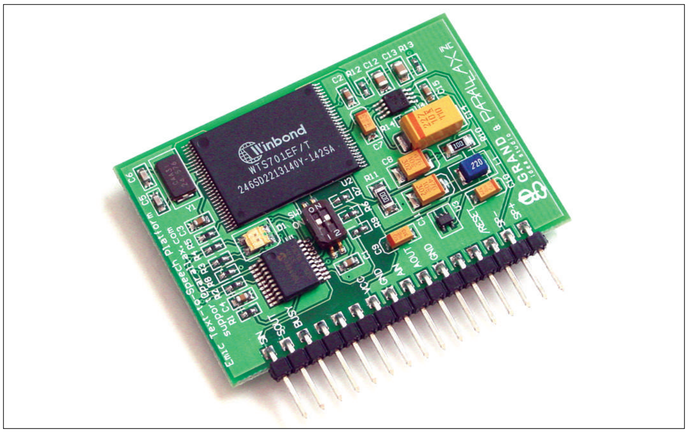
Add some eloquence to your next project — give the gift of gab!

"Speak the speech, I pray you ..." starts Shakespeare's famous instruction to the actor. The essence of this admonition is for the actor to speak truthfully and easily, without fabrication or extended effort. This is important to me because, as many of you know, I lead two lives: one as a happy-go-lucky Parallax employee, the other as a professional actor. What does this have to do with BASIC Stamps? Have faith, friend, this is my cheesy introductory text and you know I'll get there!

Almost all actors go through a stage where nothing that comes out of their mouths sounds right. Believe it or not, it takes a lot of work to sound completely natural while speaking words written by someone else — especially in the surreal atmosphere of a stage or film set. The challenge is elevated for the film and television actor, since conversations are rarely shot in a single continuous take.

So, where am I going with this? Just as the actor struggles, frequently we techno-types struggle when adding speech to our electronic projects. Sure, there are lots of neat products out there, but most (allophone based) are more difficult to use than the quality of their output warrants. It may take an hour to string together the right collection of allophones to get decent speech and, still, it usually sounds very unnatural. Yes, we ultimately get there, but, man, is it a struggle.

Figure 1. The Emic TTS (SIP version).



Enter Winbond. The company responsible for the ChipCorder® products has created a true text-to-speech product — called the WTS701 — which makes converting plain English text into high-quality spoken speech fairly straightforward. Okay, fairly straightforward is a relative term — and the WTS701 itself is a bit tricky. The device contains a rules processor for handling English text and a memory that consists of actual speech fragments that — when strung together properly — produce surprisingly pleasing, female speech. To my ear, the voice sounds a bit like that of "Mother" from the movie, *Alien*.

The Emic TTS

If you happen to go to the Winbond site (**www.isd.com**) and get the datasheet for the WTS701, you'll probably say, "Uh, oh ...," out loud. Don't worry. A Southern California company called Grand Idea Studio has created a product called the Emic Text-To-Speech Platform (Emic TTS) that shields us from the complexities of the WTS701, yet gives us access to its impressive features.

The Emic TTS comes in two flavors: an OEM version and prototyping-friendly SIP version. We're going to be using the SIP version here because it will plug right into a solderless breadboard and it includes an onboard 300 mW amplifier — all we have to do is connect an 8 Ω speaker. The SIP version also allows us to route external audio (i.e., Stamp-generated sound effects) through the WTS701 and to the audio amplifier. Another nice feature of the SIP version is that is has the same pin-out as the Quadravox QV306 modules. So, if you have a project that is using the QV306 with prerecorded speech, you can swap in the Emic TTS and update your code for direct text-to-speech output. There are advantages to both modules and I like the ability to move back and forth between them.

Just Say It, Please ...

What makes the Emic TTS so much fun to use is that it's just plain easy to make a project talk. For example:

```
SEROUT Tx, Baud, [Say, "Nuts & Volts rocks!", EOM]
```

How easy was that? All we have to do is send our text through a serial connection. As you'll see in the demo program, *Say* is the command to speak the text that follows and *EOM* is the end-of-message marker. When active, the Emic TTS will tell us by lighting a red LED and setting the Busy output high. When the current phrase is complete and we can send a new one, the LED will change to green and Busy will go low. Before we get to the code, let me discuss the two operational modes that are supported by the Emic so that you will understand why I wrote the program the way I did.

There are a couple of configuration switches on the Emic TTS. SW1 sets the command mode for the device. When SW1 is on, the Emic TTS expects commands in text mode. In this mode, the command above would look like this:

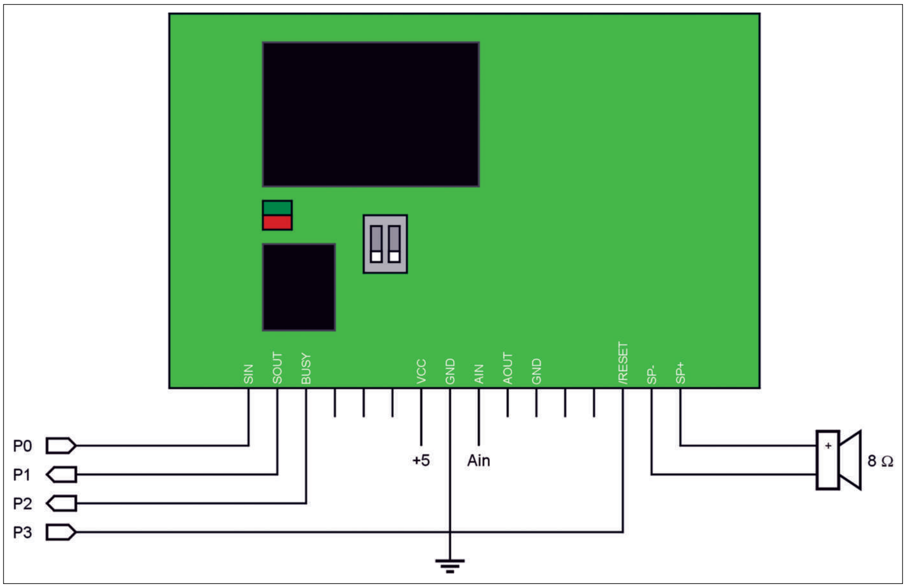


Figure 2. Emic TTS connections.

```
SEROUT Tx, Baud, ["say=Nuts & Volts rocks!;"]
```

This mode is very useful if you've got the Emic connected to a terminal program, but consumes a lot of program space when used in an embedded micro. So, we're going to set SW1 to off, which puts the Emic into hex mode. In this mode, "say=" (four bytes) is replaced with $00 (one byte), so we will ultimately save code space. To make our program easy to read, we'll create a constant called *Say* that has a value of $00. What we get is conservation of code space without sacrificing the ability to read and understand the program.

The second switch, SW2, is used to select/deselect character echo. When on, SW2 will cause every character transmitted to the Emic TTS to be echoed back. Again, this is more useful when connected to a terminal than an embedded micro. When SW2 is set to off, we don't get the echo, but we do still get status and other important information from the Emic TTS. Okay, let's get to it. Grab your Emic TTS (SIP version) and plunk it into a breadboard. The circuit is straightforward and will only take a few minutes to connect.

Stamp Based Chatterbox

The purpose of our program this month is to put the Emic TTS through its paces so we can make decisions about text, volume, speed, and pitch before installing it into that currently silent project that's just aching for a voice. The program, as written, will work on any BS2 family. Since the communication rate between the host processor and the Emic is a tame 2400 baud, you can even connect it to a BS1 — though you'll probably want to minimize the connections. Check the Parallax website for BS1 and Javelin samples, if those micros interest you.

Okay, here's what our program is going to do:

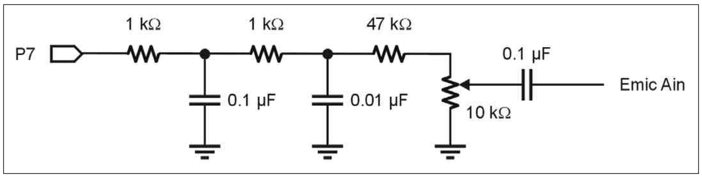
- Reset the Emic TTS
- Display a menu
- Accept and validate user input
- Run the selected demo item

The first thing we're going to do is reset the Emic TTS so that we can start in a known state. There are two ways to do this: hard and soft. Doing a hard reset requires an external control line. If you have a project that is short on I/O, you can let the Emic RST\ line float and do a soft reset through the serial link. The only downside to the soft reset process is that we have to wait if the Emic is busy. Here's our code to do a hard reset and preset a couple of program variables to the Emic TTS defaults:

```
Hard_Reset:
  LOW Rst
  PAUSE 0
  INPUT Rst
  GOSUB Wait_OK
  vol = 4
  spd = 2
  ptch = 1
  RETURN
```

The first four lines handle the reset and confirmation process. As you can see, we just need to pull the RST\ line

Figure 3. Audio Filter for FREQOUT and DTMFOUT.



low briefly, then release it to the onboard pull-up. When the Emic TTS resets, it will send an "okay" signal through the serial line. We'll need to watch for this from time-to-time, so waiting for that signal is handled in its own routine.

```
Wait_OK:
  SERIN  RX, Baud, 1000, TO_Error, [WAIT(OK)]
  RETURN
```

There's no magic here — we're just waiting for the *OK* byte. It should come right away and, if it doesn't, then we can jump out to another routine (TO_Error) to deal with the lack of response. We might, for example, construct a robot program that works fine with or without the Emic TTS. If we don't get the *OK* signal after the hard reset, we'll know that the board is not installed and our code will proceed accordingly. We do, however, have a board installed, so let's go back to the program. The next stage is presenting a menu and processing the user input. We don't frequently need menu programs in embedded controllers, but, when we do, it's nice to be able to handle them effectively — and PBASIC gives us some neat tools that simplify input processing.

```
Main:
  DEBUG CLS,
        "Emic TTS Demo Menu", CR,
        "------------------", CR,
        "[V] Set Volume (", DEC1 vol, ")", CR,
        "[S] Set Speed (", DEC1 spd, ")", CR,
        "[P] Set Pitch (", DEC1 ptch, ")", CR,
        CR,
        "[1] Demo 1", CR,
        "[2] Demo 2", CR,
        "[3] Sound Effects (uses Ain)", CR,
        CR,
        "[A] Use Abbreviation", CR,
        "[J] Japanese (phonetic demo)", CR,
        CR,
        ">> "
```

The menu is simply several lines of text pumped out of the programming port to the **DEBUG** window. Notice that the program variables for current volume, speed, and pitch are displayed, so we can take note of our results when we get what we like. The next step is command input and validation. Let's look at the code, then go through it line by line.

```
  DEBUGIN cmd
  LOOKDOWN cmd, ["vVsSpP112233aAjJ"], cmd
  cmd = cmd / 2
  IF (cmd > 7) THEN Main

  BRANCH cmd, [Set_Volume, Set_Speed, Set_Pitch,
               Play_Msg, Play_Msg, Play_SFX,
               Play_Msg, Ph_Demo]
```

The first thing we have to do is get a key from the user, so we do this with **DEBUGIN**. Since our input section is a single byte variable, we'll end up with a single key input. The next line is where the PBASIC magic takes place. **LOOKDOWN** is used to scan a table for the input variable and, if that value is found in the table, the position will be reported in the output variable. As you can see, we've used the same input and output variable with **LOOKDOWN**, so what this does is convert the input key to its position in the table. What happens if the entry is not in the table? Nothing — the output variable will not be changed.

Take a look at the table and you'll see that each key is covered by two characters. This allows us to be user friendly and treat lower and upper case letters in an intelligent manner. For the numeric characters, which have no case, we need to enter them twice. Let's go through an actual input to see why.

When we press the letter "P" on our keyboard, **DEBUGIN** will put "P" into the variable *cmd*. **LOOKDOWN** takes *cmd,* hunts for it in the table, and finds it in position five. (The first position in the table is zero.) Since "P" was found in the table, the output variable — *cmd* — will now hold five. The next line deals with our two-key situation by dividing the raw position value by two and now *cmd* holds two. (If we start counting from zero, we'll see that "P" is in position two of our menu.) The next step is validation; we need to make sure the entry is in range. If yes, *cmd* will be passed on to **BRANCH** to run the selected code; otherwise, the program redraws the menu and waits for another input.

If you haven't used **LOOKDOWN** before, you may be wondering about the duplicated entries. What happens is that the first position is put into the output variable. So, if we press "1" on the keyboard, we will end up with a value of six in *cmd*. The second entry of each number is needed to correctly position the keys that follow, since the output position must be divided by two to correct the entry.

The first three items on our menu allow us to modify the sound of the Emic TTS speech by changing the volume, speed, and pitch. Since the code for each of these entries is identical, we'll just go through the first of them:

```
Set_Volume:
  DEBUG CLS, "Enter Volume (0 - 7): "
  DEBUGIN DEC1 response
  vol = response MAX 7
  SEROUT TX, Baud, [Volume, DEC1 vol, EOM]
  GOSUB Wait_OK
  GOTO Main
```

As you can see, we clear the screen, display a prompt, and then wait for a key. To help filter the input, we use the DEC1 modifier. This will allow just one key and force it to be "0" through "9." Like our other inputs, we have to validate it before moving on. In this case, we're going to use **MAX** to make sure we don't send an illegal volume level (eight or nine) to the Emic, then we send it with **SEROUT**. One thing to note is that we actually have to send the volume level as text and not as a numeric value. There's no problem here; we use DEC1 again and that will convert the numeric volume level back an ASCII character.

Let's have the Stamp say something, shall we? You've already seen how easy it is and what we're going to do is

change the code a bit so that we can store our text strings in **DATA** statements. This will allow us to call a single routine to speak any number of text phrases we want to be said. This will also cut down on the number of **SEROUT** instructions. As I've told you before, **SEROUT** is a bit complex and consumes code space, so minimizing the number of **SEROUT** instructions will give us more room for operational code. If, for example, our robot has 50 different things that it might be able to say, we can cut down the number of **SEROUT**s from 50 to just one to say any of those phrases. Of course, this takes a little planning:

```
Say_String:
  DO
    READ eePntr, char
    SEROUT TX, Baud, [char]
    eePntr = eePntr + 1
  LOOP UNTIL (char = EOM)
  RETURN
```

The Say_String code is really easy. The program will pass the first position of the string to the subroutine and the code will loop through, sending each character to the Emic until it hits the *EOM*. A no-brainer, right? You're right, it is. Here's what a stored phrase looks like:

```
Msg1  DATA   Say, "Nuts & Volts rocks!", EOM
```

Prefixing each phrase with the *Say* code may seem redundant and, in programs that use a lot of strings, it just might be. For most, however, this is probably the most memory efficient way to store our speech phrases.

Okay, before we wrap up, let's cover a couple of extra features that will come in handy. The first is the ability to amplify an external audio signal with the Emic TTS amplifier. To do this, we have to enable the Ain pin, then apply a line-level audio signal. Keep in mind that, so long as the Ain line is active, we can't send speech strings to the Emic (standard speech and external audio are mutually exclusive). Another thing to note is that the Emic TTS volume level does not affect the external audio signal.

The circuit in Figure 3 serves two functions: First, it filters the digital output of the Stamp's **FREQOUT** and **DTMFOUT** instructions into a nice sine wave suitable for amplification. Second, it attenuates the signal down to a manageable level for the Emic TTS. The 10K pot lets us set the level of Stamp-generated audio.

In Figure 4, you can see the effect of this circuit. The top trace is the digital output from the BASIC Stamp. The lower trace is the filtered signal. As you can see, the filter output is a nice, clean sine wave that is free of unwanted harmonics and will amplify cleanly. When you play the sound effects demo, you'll hear the Emic TTS say, "Dialing 1-916-624-8333," and follow it with the DTMF tones of the phone number. A simple bit of code allows us to pass the telephone number to the Say_String and DTMF dialing subroutines with the expected results from each. Neato.

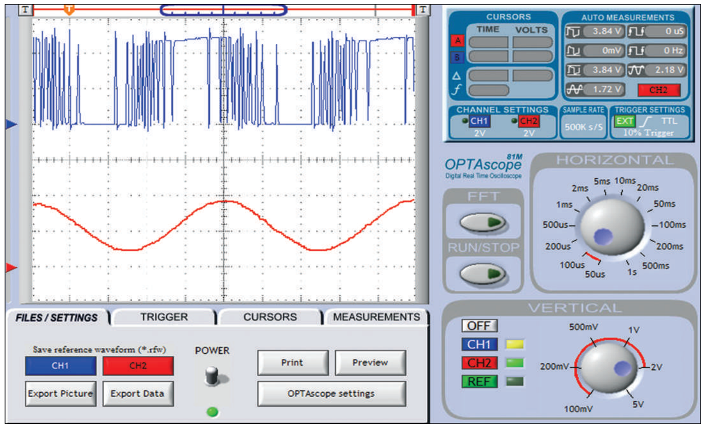


Figure 4. Audio Filter Input and Output.

```
Dial_Phone:
  DO
    READ eePntr, char
    IF (char >= "0") AND (char <= "9") THEN
      DTMFOUT AOut, 200 */ TmAdj, 50, [char - "0"]
    ENDIF
    eePntr = eePntr + 1
  LOOP UNTIL (char = EOM)
  RETURN
```

The only thing of significance in the Dial_Phone routine is the use of a constant called TmAdj. This value is used to scale the DTMF on-time for the Stamp's use, so any Stamp that runs the program will output a 200 millisecond DTMF tone. A conditional compilation section at the top of the program takes care of setting the TmAdj value for the specific Stamp.

And, finally ... there will be times when the English rules engine of the WTS701 doesn't quite meet our requirements for a given word. What we can do on those infrequent occasions is pass the word phonetically — just like we used to do with the old SP0256-AL2 and similar devices. As an example, I wanted my Emic TTS to say hello in Japanese. The Romanized spelling is konnichiwa — pronounced *cone-nee-chee-wah*. This word is stored in our program like this:

```
Nihongo  DATA    Say, PhT, "konniCiwa ", EOM
```

The *PhT* byte tells the WTS701 that what follows is phonetic text and to use those rules until a space is encountered. Note that each phonetic sound is represented by a single letter, hence the *ch* sound is represented by the single letter, C. We can also tell the WTS701 which syllable gets stressed by preceding the vowel in that syllable with a 1. Japanese is fairly evenly stressed, so we don't need it here. You won't need to do phonetic spelling very often, but it's a nice feature to have for those out of the ordinary words.

Abbreviated Flash

Oops, I wasn't quite done. There is a final feature I want to share with you — and a big caution comes along with it. The WTS701 has the ability to store abbreviations, like this:

```
SEROUT Tx, Baud, [AddAbbr, "dC,degrees Celsius", EOM]
```

After this command, we can have the Emic say, "degrees Celsius," by telling it to say, "dC." Now, here's the caveat: when we store an abbreviation, it consumes a bit of the WTS701 flash and, even though there is a "delete abbreviation" command, it doesn't free the flash, but simply marks the abbreviation as not used. Even worse, if we tell it to store the same abbreviation more than once, then we just lose flash — the WTS does not overwrite the original abbreviation as we would hope. Even if it has multiple copies of the same abbreviation, it will use the first. So, if you need to correct an abbreviation, you have to delete the original. Just remember that you don't recover any flash in the process, so be careful. These are "features" of the WTS701, not of the Emic TTS module — so, if you decide to go with another WTS701-based product, these issues will still be in place.

I learned this the hard way. While working on my demo program for this article — not knowing about the flash thing — I ended up consuming about half the available flash space in my Emic TTS by running the program over and over. I changed the code to use one of the built-in abbreviations so that the feature could be demonstrated.

Don't let this sway you from using custom abbreviations, but do let it encourage you to do so with some planning in mind. Since you can't recover the flash space with the DelAbbr command, don't do it (unless you're making a correction) because you never know when you're going to need that abbreviation in the future. My current strategy for dealing with custom abbreviations is to create a separate program to download them. In this program, I keep track of what abbreviations are currently downloaded to the Emic TTS. Note that, if you connect the Emic TTS directly to a terminal program (you'll need a level shifter), you can use the List Abbreviations command to see what has been stored.

All right, I think that's about enough for this month. You've got a great part and the code to take advantage of, so go make something talk!

Until next time — Happy Stamping. **NV**

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In The Trenches

Safety and Risk

Safety is clearly an important issue for any engineer. It covers your own personal safety and the safety of your customers. It also includes your product. Is it operating within safe limits or will it fail? Then there is the question, "Is it safe enough?" This is defined as risk.

Your Personal Safety on the Job

Engineering is not an inherently safe occupation. It is safer than many, but there are risks. You can get shocked or, perhaps, electrocuted. You can burn yourself with a soldering iron or have a serious accident with the wave-solder machine. You can drop a hammer on your foot or have one fall on your head at a job site. Fundamentally, wherever things are made, tools are used; wherever tools are used, accidents can happen.

For the most part, you are responsible for your own safety. You should know how to operate all of your tools safely. You should know what safety equipment is for and what it can and cannot do. You should be aware of dangerous situations and be able to foresee likely problems.

Trusting someone else where safety is concerned is not a good thing to do. The idea that, "They wouldn't ask me to do something unsafe," is simply wrong. Consider cigarette smoking, tobacco farming, coal mining, and working with asbestos as examples. It is true that few companies will deliberately place employees at risk. It is also true that few companies will actively search out ways to improve worker safety. Why should they? "Things are safe now. We don't need to waste money on something that may never happen." It's basic human nature to wait until an accident occurs before implementing safety precautions. Do you want to be that accident?

If you think you are being asked to do something unsafe on the job, tell someone. Ask for proper safety equipment. The federal government and many states have laws for protecting workers. You may not be required to do something you feel is unsafe. Check into your rights. Being macho is also being stupid.

Ignorance Versus Stupidity

Most safety issues occur through ignorance or stupidity. Yes, there is a difference. Ignorance is a lack of knowledge. A three-year-old who sticks something in an electrical outlet is ignorant. Stupidity comes from lack of forethought. An adult who sticks a knife in a toaster to retrieve some bread and gets zapped is stupid. Let's look at a couple of examples. An engineer was working on a prototype that needed a lithium battery soldered into the circuit. He didn't have any batteries with solder tabs, so he tried to solder wires directly to the body of the battery. The battery exploded, causing very minor injuries. The engineer should have known better. Haven't we all seen the warnings? "Do not dispose of in fire. Battery may explode." He wasn't thinking about what he was doing; he was being stupid.

A friend was about to take uninsulated pliers to remove pieces of a light-bulb socket that had broken off in a ceiling fixture. He turned off the power switch, but not the circuit breaker. Was he safe? After all, the switch controls the hot lead.

No — I warned him that he was not safe at all. First, he was trusting that someone else had wired the switch properly. While this is probably true, it is not guaranteed. Second — and much more importantly — the light was controlled by two different switches. This two-way switch configuration gave him a 50% chance of having the hot lead switched to BOTH light bulb contacts. Surprised? Work out the circuit for yourself and see. This is ignorance. The wall switch is supposed to control the hot lead. He had no idea that different switches were wired differently.

Risk Assessment

This is where we have to take a slight detour into risk assessment. It's something we do every day, but, often, we aren't aware of it. Every time we drive or cross a road, we take a risk, but we also assess the situation for safety. If the road is busy, we're more careful. Proper risk assessment requires the understanding of the elements of the situation. Often, these elements are available. An ability to assign a likelihood to an event is also required. Generally, this is also possible. Unfortunately, many people (perhaps most) fail to consider the probability of such an event occurring.

Let's look at two very similar events: the Unabomber and the anthrax letters of a few years ago. Both killed or injured a similar and relatively small number of people. Both used the mail as their vehicle. Both were fairly recent. Both were (apparently) the work of domestic terrorists. However, the Unabomber had virtually no effect on mail service or

how people perceived the safety of that service, but the anthrax mailings had many ordinary people afraid to open their mail. (I knew some. You probably did, as well.) Why the difference?

Without being political, the basic reason is that the anthrax letters were publicized to a huge extent. They were very political and initially appeared to be related to the events of 9-11. People generally reacted emotionally — rather than intellectually — to the danger. The result was that their risk assessments were flawed. For many people, the risk appeared much greater than it really was. What's more, this is not at all uncommon.

Low probability events are peddled everyday by salesmen, politicians, and others who have public agendas. It's everywhere and has probably been around forever: bomb shelters in the 1960s, duct tape, and plastic more recently, lotteries, water purity, antibiotic counter cleaners, CRT radiation. I'm sure you can think of more.

Conversely, other very serious risks are downplayed or simply ignored. According to the Department of Transportation (**www.dot.gov**), 17,400 people died in traffic accidents in 2002. CBS News (**www.cbsnews.com**), referencing the World Health Organization, pointed out that 4,900,000 people died from tobacco-related illnesses worldwide in 2002 alone — nearly five million people! A recent *Washington Post* story says, "According to the Harvard Center for Risk Analysis, the annual odds of dying of heart disease are 1 in 397 ... cancer are 1 in 511 ... car accident are 1 in 6,745 ... homicide are 1 in 15,440 ... bioterrorism are 1 in 56,424,800."

The point I'm trying to make is that proper risk assessment starts with an individual who is willing and able to analyze a situation and come to a reasonable conclusion about what to expect. Engineers are supposed to be good at doing exactly this. Engineers, as a group, have analytical minds and are independent. Unfortunately, engineers are people, too; it's easier not to think. I should also say that such fundamental risk assessments don't require a pencil and paper. It's just a basic understanding of probability and statistics. (There are lots of good books on various aspects of risk.)

Protecting Yourself

As I said before, the most important elements in safety are knowing and thinking. Common sense goes a long way. I like the saying, "The most dangerous tool is the one in your hand." Don't force tools to do something they weren't designed to do. Don't try to drill glass with regular bits. Don't measure high voltage with a low-voltage probe. Stop and think.

Don't wear metal jewelry on your hands or wrists when reaching into something electrical. Obviously, they can touch contacts and conduct electricity into you. Worse, there is generally more sweat under the metal because the perspiration can't evaporate. This salt water creates a low conductivity path and can significantly increase current through the flesh.

Just because the voltage is low doesn't mean you are safe. A mechanic was changing a starter switch in a car and didn't disconnect the battery. His ring touched the power terminal of the switch and the chassis at the same time. The full power of the battery surged through the ring. It first welded it in place and then it heated it red hot. The results weren't pleasant.

Don't work alone with anything that can get you into trouble. You may not need to have someone looking over your shoulder, but someone should be within shouting distance. Don't rely on a cell phone. If you're out cold, you can't make a call. For example: A worker got in early to do some drywall work, but, when he removed a piece of drywall from a stack which was leaning against a wall, the stack fell over onto him. He was pinned for over two hours until

others came on the job. Always be vigilant. Look and see where and how problems can occur. Can something tip over? If so, where will it fall and what will happen? Are the wheels locked? Is the power off? Are you sure? What could happen if you drop a tool when working over some equipment? Is there high voltage or high current near where you are working? I'm sure you've heard the saying, "Drive defensively." It applies to everything you do, as well. "Work defensively."

Whenever I work on household wiring, I always do checks with a voltmeter and then with my hand. I figure it's better to get a shock when I expect it, rather than unexpectedly. I touch the wire with the back of my hand, rather than with my finger tips. This is because, if there is current present, the shock will tend to contract the muscles. If the wire is in front, I might close my hand on it. By keeping the wire behind my hand, I eliminate that possibility.

Protecting Others

You certainly have the right to risk your life and health as you see fit. You can sky dive, race cars, or enter a boxing ring. However, you do not have the right to risk anyone else's without their knowledge or consent. This seems painfully obvious; however, engineers are sometimes placed in situations where this is not obvious.

Suppose you are asked to find ways to reduce the manufacturing costs of hydraulic hoses. You determine that substituting a cheaper braid will provide a cost savings. However, at low temperature, there is a greater chance of hose failure under pressure. A trade-off — it happens all the time. Your company goes with your recommendation, but, a few years later, there is an airplane crash because your hydraulic hose failed at high altitude, where the temperature was very low. Now, things are complicated.

It is important to think about how your product is going to be used when you are designing it. Are any common failure modes dangerous? Can normal use make your product a danger? Can common, abnormal use be a problem?

The All-American Five

From just after World War II until the AC-powered transistor radio was developed, many (most?) table radios were the "All-American Five" type. That is, they had five tubes and no power transformer. The transformer was probably the most expensive part, so eliminating it was very cost effective. This design forced one lead of the AC power to be connected directly to the metal chassis. Since the AC plugs of the time were not polarized, there was a 50-50 chance that the hot lead would be connected

to the chassis. This was not too much of a problem, as long as everything was insulated — hence the plastic case and plastic knobs. These knobs, however, were just pushed onto the split-knurled shafts of the controls. They were always falling off and had to be pushed back on. Often times, they fell off and rolled under the couch or just got lost. This meant that the radio was often operated with exposed metal that was in direct electrical contact with the chassis.

Now, suppose you were bathing in your cast iron tub with nice copper pipes going deep into the ground. The radio is playing your favorite song, so you reach out of the tub with your wet hand to turn up the volume. The knob is gone, so you twist the bare metal that connects to the chassis, which is connected to the hot lead of the AC power. What do you think happens?

Better circumstances for electrocution are difficult to achieve. The current flows through the torso with low resistance at every point directly to an excellent ground. Even if you aren't immediately killed, there's a good chance that you will drown. When the electricity passes through your hand, it contracts onto the shaft because of muscle spasms. Then, when you fall, the radio is pulled into the tub with you. (Deaths from this scenario were not all that rare.)

There are two points to this. The first is that the death was usually attributed to the radio falling into the water and that was what caused the electrocution. However, if you stop and think, you will realize that this is unlikely to cause a significant shock. Electric current wants to go to ground. It takes the path of least resistance. Assuming the radio doesn't fall into your lap, the easiest path is either through the water and metal tub to ground or through the return wire of the radio itself. Even if it does fall into your lap, the current isn't likely to pass through the torso and cause your breathing or heart to stop. (Although I haven't personally tried it.) The second point requires some additional information. On the cord of all of these radios was a label that said "UL Approved." UL means Underwriter's Laboratory. That sticker meant "safe." Most everyone thought that the radio was safe. The truth was that the UL mark only referred to the power cord. The power cord was safe when used properly. The radio was not UL approved.

I'm using this example to graphically illustrate many facets of safety and risk: an unsafe design based on cost-cutting measures; the perception of safety with the UL sticker on the cord; the ignorance of the user; the tacit acceptance of major manufacturers and government. Of course, such things could never happen today. Or could they? I can think of several examples that parallel the radio

example. (Although they do not apply to consumer electrical products.)

All of this shows that the responsibility to warn is important, ethical, and, often, legal. If your product fails when it's cold, that should be noted, not covered up. A risky "standard design" is still risky and the users should be warned. Examine the situation from the user's point of view. How would you react to a failure? Would your reaction be different if you discovered that information was withheld?

Safe Design

To this point, we've discussed personal safety. There is also the safety of property to consider. Obviously, this is less important, but the concepts of risk and safety apply here, too. You want your product to operate well for a long time. It's clear that failing products can easily lead to a failing company. It's also easy to see that safe design and product quality are related.

Most often, poor designs fail for the same reasons that accidents happen: ignorance and/or stupidity. An engineer working in a new area makes mistakes because he doesn't have the experience or an engineer has done similar designs for so long that he gets bored and ignores subtle — but significant — variations. Good engineering requires equal amounts of common sense and attention to detail. Know your limits.

If you are asked to do something you don't think you are capable of, tell your boss. Most likely, he'll appreciate your honesty. On the other hand, he will definitely not appreciate months of floundering, followed by a product that doesn't work. Your limitation might be turned to your advantage; perhaps you can take a course or go to a seminar. That will enhance your capabilities; learning new things is never a waste.

Use plenty of error margin when designing. For example, the common 1N4001 rectifier diode has a reverse voltage rating of 50 volts. The 1N4002 is rated at 100 volts; however, the price is the same. In fact, in reels of 5,500, all the 1N400X series — including the 1,000 volt version — are the same price, according to Digi-Key. (Other sources, like Mouser and Jameco, may vary the price slightly for the much higher voltages.) So, if your power supply requires 35 volt rectifiers, why not use 100 volt parts instead of 50 volt parts? This example also raises a significant point. It's important for you to know the practical aspects of design. If you use marginal parts, the design may fail. If you use expensive parts, the design may not sell. As always, the more you know, the better you are able to design. The better you design, the safer and more reliable your product will be.

Finally, you should know the failure modes of your design. Your design should "fail-safe." This fail-safe idea has two parts. The first is that any single failure should not cause the product to be a danger to people or property. The second is that a failure of one part should not cause failures in other parts, also known as a "cascade failure."

Fail-safe design requires the engineer to understand the common failures of basic parts. For example, will the power diode most likely fail open or shorted? What will be the result? Will a signal diode fail in the same way? What about capacitors and resistors? It's much easier to consider these points as you design the product, rather than later. Get into the habit of looking for problems. "Design Defensively."

Accidents Will Happen

Obviously, no one can be perfectly safe all the time. No one can create a completely harmless product; you can always drop it on your toe or stick it in your eye. Accidents will always happen. Sometimes, it isn't your fault. There's little you can do if a bridge fails as you drive over it. Sometimes, your actions attract an accident — like playing golf during a lightning storm.

Conclusion

Safety and risk are important everyday considerations for everyone. Generally, you are responsible for your own safety. You decide if your actions are safe or not. You decide to wear safety equipment or not. Engineers have special concerns. They work with tools, machines, and electricity. They create products for others to use. They decide how safe safe enough is. These are responsibilities that should always be taken seriously. **NV**

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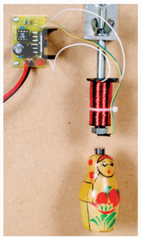

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digital principles and the analysis of MPEG images. Does anyone have any ideas about how to do this?

The answer lies somewhere between the extremes of your light sensor experiments and the analysis of MPEG images. A frame of video contains much more information than is required to accurately detect a scene change. The trick is identifying the minimum information required. From the description of your experiments with sensors, it appears that you attempted to discern scene changes by measuring changes in average luminescence. While some scenes do vary from the following scene in average luminescence, this measurement alone will not suffice because a myriad of different scenes can exist with approximately the same average luminance.

The shape of the video envelope within a frame, however, is a unique scene characteristic which is easily compared to the envelopes of other scenes.

In a proof of concept experiment to detect rapid scene changes, the video signal from a TV was passed through a low pass filter so that the unwanted high frequency components were filtered out, leaving just the envelope. Using the vertical sync as a trigger, equally spaced samples of the envelope amplitude were taken during successive fields. Like samples from successive fields were compared and the unsigned differences (the difference could be positive or negative) were summed over the interval of the field. A summation value exceeding a threshold value defined a scene change.

Incidentally, a blank frame can easily be detected from the same data by comparing the magnitude of the summation of samples in any given field to another threshold value. It is not necessary to distinguish between fields and frames in an interlaced video format, as the two fields which constitute a frame will have nearly identical envelopes.

Allen Fulmer
Seminole, FL

[10412 — January 2004]

I want to create a digital thermometer with a four Nixie tube display. Can anyone point me in the right direction?

If you can light up a neon lamp, you can drive a Nixie tube (well, almost). A Nixie tube is basically 10 neon lamps in one package with a common terminal. You apply current-limited high voltage to the common terminal and the segment you want to light up. That gives you the lighted number.

To make the thermometer, you need a temperature sensor, a sensor-to-reading formatter (probably a microcontroller, but it could be CMOS logic), a high voltage source, and a level translator/driver circuit. You could use high voltage transistors or FETs to drive the Nixie tubes. The high voltage is at very low current, so you could use a DC-DC converter or just set up line voltage with a capacitor-diode doubler. Take a look here: **www.decodesystems.com/nixie.html** for some Nixie info.

Robert Zusman
Scottsdale, AZ

[2046 — February 2004]

I have a standard personal computer that has serial inputs. Is there an adaptor I can build or purchase to add USB ports to my machine?

The best thing to do is to use an expansion slot of the computer to add USB ports. While some USB devices are meant to be backward-compatible with RS-232 serial devices, the reciprocal is untrue and would be difficult to implement. If you have an unused PCI slot, get a PCI USB expansion card. Typically, you will get four or five USB 2.0 ports and the card should cost under $20.00.

Wendell Wilson
Richmond, KY

[2044 — February 2004]

I have several USB flash memory sticks that I like to use simultaneously. Most USB "hubs" have the (typically, four) receptacles so close that, at best, I can get three USB sticks in and, sometimes, only two. What I need are some short (preferably about eight inches or less) USB extension cables.

#1 On your quest for custom USB extension cables, I'm sure you know that finding the female end is the tricky part. Digi-Key (**www.digikey.com**) offers two of the A style (flat

USB type) with about eight inches of cable under the part number AE1161-ND for $7.10.

You could then buy the male; AE1134-ND for the USB A style or AE1136-ND for the USB B style (square USB type) to solder onto the other end of each cable. Each one is about $1.00.

Brian German
via Internet

#2 Cyberguys! (**www.cyberguys.com**) sells six inch USB extension cables that will eliminate your bottleneck at the USB sockets. Stock #131 0938; they cost $1.79 each.

Michael Schuster MD
Leonia, NJ

#3 I had similar troubles with programming lots of USB memory sticks quickly until I finally located a vendor that sells a USB hub that has the ports mounted vertically, instead of horizontally. TigerDirect (**www.tigerdirect.com**) sells a 7-port USB 2.0 hub. Simply go to their website and put C184-29560 in the search box at the top. It is $39.99 before the $10.00 mail-in rebate. You can see from the picture on the website that the ports are spaced far apart and turned vertically. With this, I am able to use seven Lexar USB memory sticks at a time.

Wendell Wilson
Richmond, KY

2043 — February 2004]

I noticed that your magazine is for the beginner, as well as the professional. Where does someone start who is interested in electronics?

There are many resources to help you locate a mentor who will get you started in electronics. These include Hamfests, Local Scout and Explorer groups, local TV repair shops, electricians, telephone company retiree organizations (such as Telephone Pioneers), etc.

Check out your local community college for a basic electronics course. They are likely to be heavy on math and theory and light on hands-on work.

You'll need a workbench. Then start acquiring tools of all kinds. Check out flea markets and yard sales. Your training starts with taking things apart — things electrical and mechanical, including washers, dryers, TVs, microwave ovens, computers, floppy drives, dial telephones, etc.

At Hamfests, you can meet people interested in starting a class. You might also meet some like-minded guys who help each other with resources and ideas. Look for a mentor to start up a group activity and build some simple projects. A lot of stuff gets thrown away that could be taken apart for its educational value. Don't forget the Internet as a source of valuable info.

Fred Mocking
Skokie, IL

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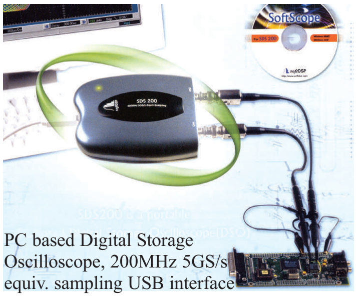

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